TELEPHONY

VOLUME II

TELEPHONY

A DETAILED EXPOSITION OF THE TELEPHONE EXCHANGE SYSTEMS OF THE BRITISH POST OFFICE

BY

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PREFACE

The first volume of this work deals with the more elementary principles of telephony and in particular with subscribers' station apparatus and the various manual exchange systems. This second volume is devoted mainly to the theory and practice of automatic switching, and has been written primarily for students of telephony and for those engaged on the construction or maintenance of telephone exchange equipment. It has been assumed that the reader has some knowledge of elementary d.c. and a.c. theory. The two volumes together are designed to meet the syllabuses of the City and Guilds of London Institute examinations in *Telephone Exchange Systems*, Grades I, II, and III (and the telephone aspects of *Elementary Telecommunications Practice*).

The facilities, switching principles, and circuit descriptions in this volume relate almost entirely to the current practice in the United Kingdom and in certain Commonwealth, Colonial, and other countries where standard British automatic exchange equipment is used. Brief descriptions have, however, been given of the more common automatic switching systems used by other telephone administrations.

Up to the present time all practical automatic exchange systems have been based on the use of electromechanical switching devices with control circuits which are often extremely complex. This complexity arises from the numerous separate and successive functions of each circuit during the establishment of a call. A selector circuit may, for example, have to position a mechanism from the signals received from the subscriber's dial, to provide automatic search over a selected group of lines, to ring the required subscriber, to return an engaged signal if the required line is engaged, and so on. In some instances, the circuit may be arranged in a score of different ways, the electrical connexions at any particular time depending upon the stage reached in the process of selection and upon the conditions encountered. These circuit re-arrangements are normally effected by contacts of electromechanical relays which are operated and released in various combinations to give the desired circuit connexions. In studying automatic switching circuits, it is important firstly to know the exact facilities provided and secondly to appreciate how the relays are used in combination to provide the correct conditions for each function. Little is to be gained by memorizing complete circuits, and it is preferable that the student of telephony should concentrate on obtaining a thorough understanding of the fundamental elements upon which the complete circuits are built. I have attempted in this volume to analyse the many problems of automatic telephony and to examine the merits and limitations of the various recognized circuit elements. In the later chapters of the book a number of complete circuits have been described, so that the reader can see how the basic circuit elements are associated to give the desired facilities.

The first chapter discusses the objects and advantages of automatic switching, and describes the broad principles of the step-by-step system. This is followed in the second chapter by an examination of the theoretical aspects of telephone traffic, the quantity of switching equipment required and the methods of interconnecting the equipment. This leads to the descriptions in Chapter III of the standard switching mechanisms, and thence, in Chapter IV, to the physical design and the general cabling arrangements of an automatic exchange. These first four chapters thus provide a broad picture of automatic exchange design without entering into details of the circuit arrangements.

Chapters V to X are devoted to an examination of the various component circuit elements on a "functional" basis, whilst Chapter XI shows how the previously considered elements are integrated in typical selector circuits. Chapters XII to XVI describe in somewhat greater detail the trunking arrangements and the special circuits used in the "Non-Director" and "Director" systems and in the several "Unit Automatic Exchanges." Chapter XVII describes the facilities required and the circuits employed for establishing communication between manual and automatic exchanges.

The next four chapters (XVIII to XXI) contain brief descriptions of a number of other automatic systems which have been widely used by various telephone administrations,

whilst Chapters XXII and XXIII deal with the problem of dialling over long distances and the mechanization of toll and trunk switching. The four final chapters (XXIV to XXVII) describe various miscellaneous facilities, modern automatic exchange power plants, and the problem of converting from an existing manual exchange to a new automatic system.

I would like to place on record my grateful thanks and deep obligation to Sir Archibald J. Gill, B.Sc., M.I.E.E., F.I.R.E., Engineer-in-Chief of the Post Office, for his kind permission to use official information, diagrams, etc., without which the publication of this book would not have been possible. I would also like to tender my sincere thanks and appreciation to many friends in the Post Office and in the telephone manufacturers' organizations who have so generously assisted in various ways. I am, in particular, indebted to Miss H. N. McLellan for her invaluable assistance with the typescript, and to Mr. G. Howard who has devoted long hours to the preparation of the illustrations. It gives me great pleasure also to acknowledge my indebtedness to Mr. R. W. Palmer, Mr. H. Leigh, and Mr. S. Welch for valuable comment on certain sections of the manuscript, and to Mr. J. McEachan who assisted in the analysis of some of the more complex circuits.

I am pleased to acknowledge my obligation to the following firms who have supplied illustrations or special information relating to the apparatus which they manufacture—

Automatic Telephone and Electric Co., Ltd.
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My thanks are due also to Mr. W. S. Procter for kindly permitting the use of material and illustrations from *Telephony*, Vol. II (1938 edition) and to the Australian Post Office for permission to reproduce photographs of the Melbourne trunk exchange. I would also like to record my indebtedness to the Institution of Post Office Electrical Engineers, whose publications have been freely used, and to the City and Guilds of London Institute for permission to reproduce extracts from past examination papers.

In a work of this magnitude it is possible that, in spite of careful checks of the proofs, some inaccuracies may have escaped detection. I would much appreciate advice (under cover to the publishers) from readers who may observe any such errors.

J. A.

London,
July, 1950

CONTENTS

TELEPHONY

AUTOMATIC EXCHANGE SYSTEMS

CHAPTER I

ELEMENTARY PRINCIPLES OF AUTOMATIC SWITCHING

Introduction. In a manual switching system, the connexions between subscribers are set up by a telephonist on receipt of verbal instructions from the calling subscriber. In an automatic system, on the other hand, calls are established by means of signals from the calling subscriber which control electromechanical switching equipment located in the exchange. The use of the word "automatic" to describe a system in which the operations carried out by the subscriber are in fact more complex than in a "manual" system, is perhaps not strictly accurate. The phrase *machine switching* would in some respects be more descriptive, but by common usage any system in which calls can be established without the aid of an operator is nowadays always referred to as an *automatic system*.

The idea of automatic or machine switching is by no means new. The first patent* for an automatic switching system was granted in 1879, i.e. within four years of Graham Bell's invention of the telephone and almost immediately following the opening of the first commercial telephone exchanges. During the next decade there were a number of patents, both in America and in Great Britain, for automatic switching schemes but, generally speaking, these early ideas were either crude and impracticable or limited in their application. In 1891 Almon B. Strowger of Kansas City patented† a system of automatic switching which contained the basic idea of a 2-motion selector for establishing communication between two subscribers. The original scheme required five wires from each telephone to the exchange and has now been replaced by a system of signalling over the basic speaking pair by the use of a rotary dial. Nevertheless, the principle of the selecting mechanism described in the patent forms the basis of the modern *Strowger system* of automatic telephony which has been adopted as standard in Great Britain and in a number of other countries.

* Connolly, Connolly and McTighe—U.S. Patent No. 222458, 9th December, 1879 (British Patent No. 5114, 13th December, 1879).

† U.S. Patent No. 447918, 10th March, 1891.

The first public automatic exchange was opened in 1892 at La Porte, Indiana, and during the next ten years some twenty or thirty exchanges of various types were installed in the U.S.A. In this country several demonstration installations were provided from 1897 onwards but the first automatic exchange for public service was not opened until 1912 (at Epsom, Surrey). The Great War of 1914 naturally retarded the development of automatic telephony but, with the restoration of peace in 1919, the change of social and economic conditions added new incentives to the development of machine switching. Prior to the war, female labour was cheap whilst mechanical switching equipment was comparatively expensive. Hence, although automatic telephony had a number of service advantages it did not in many cases show any real economic merits over the highly developed C.B. manual system. After 1918 the general level of wages was very much increased whilst, on the other hand, the development of mass production methods during the war appreciably reduced the cost of automatic switching equipment. Under modern conditions automatic switching has, in addition to its service merits, a pronounced economic advantage over manual switching systems. About 70 per cent of the total subscribers of the United Kingdom are now connected to automatic exchanges, and it is the policy of the British Post Office to provide automatic switching for all calls up to 15 miles radius from the calling subscriber. There are no fundamental technical reasons why automatic switching should not be employed for calls over greater distances, but, at the present time, it is the general policy that a subscriber should have the assistance of a telephonist for the setting up of the longer and more expensive calls.

Service Considerations. Automatic switching offers to the subscriber a number of service advantages. The more important of these are:

1. Phonetic errors due to the oral repetition of a number from the subscriber to an operator (or from one operator to another) are entirely eliminated. In cosmopolitan areas such as are found in the Near

and Far East in particular, the adoption of automatic switching eliminates to a large extent the difficulty experienced in operating exchanges which serve multi-lingual areas. In such areas the dial of the automatic system can be engraved in two or more languages to cater for practically every member of the population. Phonetic errors are particularly troublesome in heavily telephoned areas where calls may be routed over two or three junctions in tandem with the consequent verbal repetition at each switching stage.

2. Since the switching apparatus in an automatic exchange is remotely controlled by the subscriber himself, a much higher degree of secrecy is obtainable.

3. All subscribers on an automatic system receive the same service and any possible favouritism by a telephonist is eliminated.

4. The service is unaffected by sickness or strikes.

5. The registration of call charges is automatic and more reliable.

6. Calls can be established and released more rapidly than in a manual system. More important still, the time taken to set up a call under machine switching conditions is substantially constant at all times of the night or day and is independent of the volume of traffic. Calls on an automatic exchange are released within a fraction of a second of the calling subscriber replacing his receiver. This is a great advantage to business subscribers who may require to make a number of calls in quick succession.

Although the service advantages of automatic switching are now widely recognized, manual switching methods may be considered preferable under certain conditions. The main arguments in favour of manual working are:

1. The process of dialling places too much responsibility upon the subscriber.

2. The "personal" attention of a telephonist is more satisfactory to the subscriber than the "robot" attention of machine switching equipment.

3. Manual equipment can be manufactured and installed in a much shorter time than automatic equipment of the same capacity. It is therefore more suitable for meeting unanticipated growth in an area and it is easier to replace if an exchange should be partially or totally destroyed (e.g. by fire or war).

4. It is sometimes argued that the very complex electromechanical equipment of an automatic switching system is the cause of more failures than the phonetic or other errors introduced by the human control in a manual system. Whilst this argument may have been tenable during the early days of automatic telephony, the continued development and improvement of automatic switch ing circuits has now reduced the number o mechanical and electrical failures to a very smal order.

5. For economic reasons the quantity of auto matic switching plant is limited to the amoun required to meet the *normal* maximum traffi demands. In a manual system, on the other hand the traffic handling capacity of the exchange ca be temporarily increased to meet abnormal con ditions by a concentrated effort of the telephonist during the busy period.

6. A manual switching system does not requir the same high standard of external plant main tenance as is necessary for an automatic system.

Economic Considerations. The initial capita cost of automatic switching equipment is appre ciably greater than that of a manual exchange c the same capacity. The higher initial cost of auto matic equipment may be the deciding factor i favour of manual working in a small privatel owned telephone system, but in a large administra tion with extensive capital resources, the initi cost is not of vital importance.

In all economic studies it is necessary to compa the total *annual costs* of providing the service wit the corresponding *annual income* resulting fro that service. In order therefore to compare tl working costs of two alternative systems, it necessary to determine the *annual charges* of eac phase of the expenditure. The total annual charg of a telephone exchange may be broadly divide under the following headings:

1. *Wages and Establishment Charges of Operati Staff.* The number of telephonists required in a automatic switching system (for assistance a long-distance calls) is usually less than one-quart of the number required for a similar manual e change. The consequent savings are a major fact in favour of automatic working. If it is assume that each telephonist incurs a total charge of, sa £250 per annum, a saving of 20 telephonists repr sents a reduction of £5000 in the annual charges f the system. This £5000 would probably bear tl interest and depreciation charges of more th £50 000 worth of automatic equipment. It is inte esting to note in passing that, under automat conditions where a telephonist is required only f the establishment of long-distance calls, the wo of the telephonists is much more interesting th in a manual system where a high percentage of t time is spent in completing simple and uninteresti local connexions.

2. *Wages and Establishment Charges of Engine ing Staff.* The maintenance of automatic switchi equipment requires engineering labour of hi

mechanical skill and equipped with electrical knowledge of a high standard. The circuits of manual systems are, on the other hand, comparatively simple and not only is the number of engineering maintenance staff less, but the qualifications of the staff may also be of a lower level. The greater number of maintenance staff, the higher average wage of this staff and the increased cost of training make the annual charges under this heading materially greater for automatic switching than for a manual exchange system.

3. *Interest on the Capital Cost of the Equipment.* Owing to the higher initial cost of automatic switching equipment, the annual payments to provide the interest on the capital expenditure are consequently much higher than in a manual system.

4. *Depreciation and Renewal Costs of Equipment.* The life of automatic equipment is, perhaps, somewhat less than that of manual plant due to the rapid development of the art of automatic switching. This results in annual charges somewhat greater than in a manual system.

5. *Maintenance Replacements.* Apart from the question of maintenance labour, the wear and tear on the component parts of machine switching equipment is fairly high and the annual maintenance replacement charges are correspondingly greater than in a manual exchange.

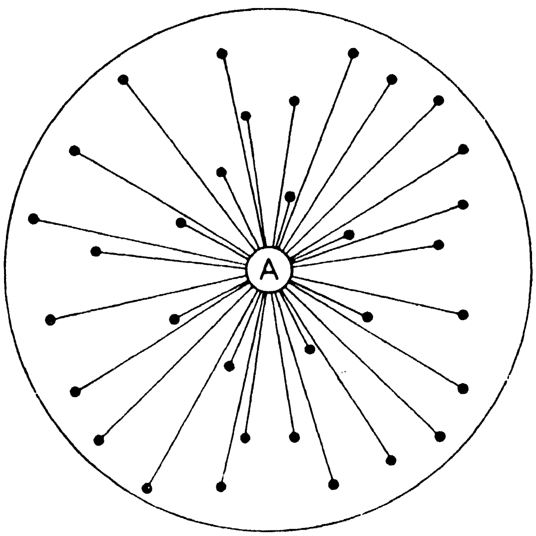


Fig. 1. Hypothetical Exchange Area Served by a Single Exchange

6. *Interest on the Capital Cost of the Building and Site.* The adoption of automatic switching allows more latitude in the shape of a building and hence in the shape of a site for a new exchange. Automatic equipment can be installed in one or more rooms of irregular shape, whereas with a manual system the accommodation must be suitable for a long line of switchboards with adequate natural lighting and the requisite volume of air for the large operating staff. The location of any exchange is determined by the most economical arrangement of external cables and in practice it falls almost invariably in the business centre of an area where land values are high. It is therefore a material advantage if an available site of perhaps awkward shape can be utilized for an exchange. Moreover, the decrease in the number of operators in an automatic system enables appreciable economies to be made in the total floor space required for welfare accommodation. It follows from the above that the smaller space required under automatic switching conditions also reduces the annual maintenance and depreciation charges for the building.

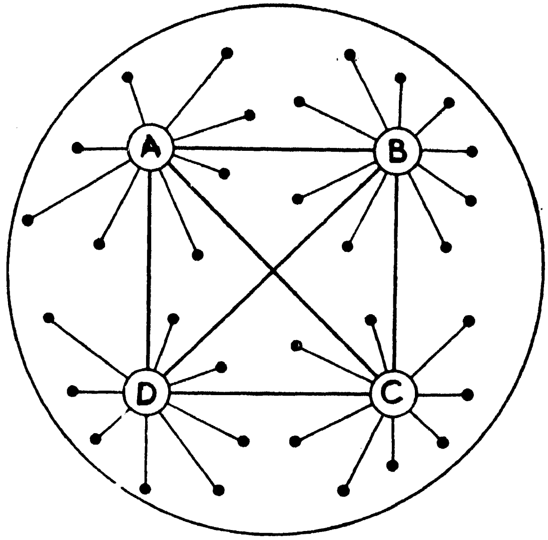


Fig. 2. The Same Area Served by Four Exchanges

7. *Cost of Electrical Energy.* The power consumption of an automatic exchange is somewhat greater than that of a corresponding manual system, but this item is comparatively insignificant as compared with the remaining annual charges.

Effect on External Plant Economics. In certain areas considerable economies in the cost of external plant can be obtained if the area is divided into a number of smaller exchanges linked together by short junction routes. The problem is illustrated simply in Figs. 1 and 2. Fig. 1 shows a hypothetical

town served by a single exchange A. A number of the subscribers are on the fringe of the exchange area and the external plant costs for these lines are correspondingly high. If now four exchanges (A, B, C, and D of Fig. 2) are provided in place of the one central exchange A, the aggregate length of the subscribers' lines is very much reduced. This saving is, of course, offset to some extent by the necessity of providing junction routes between the four exchanges serving the area, but a comparatively small number of junctions will suffice to

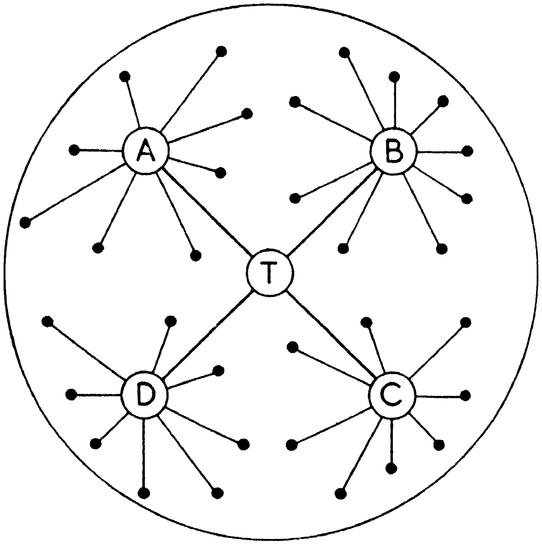


Fig. 3. Introduction of a Tandem Switching Point

carry the maximum simultaneous traffic from a large number of individual subscribers. There is, therefore, a very material overall saving *provided that the subdivision of the switching equipment into four units does not materially increase the switching costs*. With a manual system one operator only is required per call if the area is served by a single exchange; but if the area is now divided into four portions it is probable that some 75 per cent of the calls will be to subscribers on other exchanges in the area and will involve the attention of *two* operators per call. It is clear that the operating costs are greatly increased by dividing the area in order to effect economies in the external line plant. Moreover, by breaking up the operating force, the supervision costs and the total welfare accommodation costs are also increased. Furthermore, under manual working, the operating procedure becomes slow and the general standard of service would suffer if an area were so divided.

With automatic switching these considerations do not apply and the total quantity of switching equipment is substantially the same whether it is concentrated in one building or is divided into four exchanges conveniently placed from an external line plant point of view.

The introduction of automatic switching also enables economies to be made in the length and number of the inter-exchange junction circuits. If a tandem switching point (T) is introduced as shown in Fig. 3, four shorter and more efficiently worked junction routes can replace the six individual routes required in Fig. 2. Under manual switching conditions the introduction of a central tandem point is generally inadmissible due to the fact that it still further increases the operating charges by introducing a *third* operator (the tandem operator) on a high percentage of calls. Moreover, with such a scheme the service would be intolerably slow and the number of phonetic errors would greatly increase. With automatic switching the introduction of a tandem switching point requires a certain amount of additional switching equipment but, in a large number of cases, the cost of this equipment is more than outweighed by the consequent savings in junction costs.

Densely Telephoned Areas. It was realized some considerable time ago that automatic switching had particular merits in a heavily telephoned area such as, for example, the City of London. The capacity of a manual switchboard is limited by the space required for the multiple jacks and there is a definite limit of about 10 000 lines for manual switchboards of normal design. In an area where the rate of growth is high, it is therefore necessary to open up more and more exchanges to serve an area which previously was served by perhaps one or two switching points. The introduction of new exchanges increases the proportion of junction traffic from each exchange in the area and the operating costs consequently rise.

Assume, for example, that initially a certain area can be served by one exchange as shown in Fig. 1. As the service grows and more and more subscribers are connected, a point is reached when the capacity of the switchboard is exhausted and it becomes necessary to open up a second exchange. In due course this second exchange is filled up and so on until, at some particular stage in the development of the area, four exchanges are required as shown in Fig. 2. It is apparent from the previous considerations that the operating costs under manual switching conditions are now much higher than the costs for the same type of call when only one exchange served the area. It is a recognized characteristic of telephone service that in congested areas the operating cost per call grows rapidly as the system develops. Apart from the

undesirable procedure of increasing the call charges, the only solution is in the adoption of automatic switching which enables new exchanges to be opened and additional switching points to be introduced without a very great increase in the total switching costs per call.

Rural Areas. Whilst automatic switching is possibly the only economic means of providing telephone service in a densely populated area, it is interesting to note that the advantages of machine switching methods are also most pronounced under conditions which are diametrically opposite. Before the advent of automatic telephony the provision of telephone service to small rural communities presented a major economic problem. The number of subscribers connected to one exchange is usually very small and the revenue resulting from calls does not normally justify the provision of a separate exchange building. In a very large number of cases in fact the traffic does not warrant the provision of a full-time operator and arrangements must be made to install the switchboard in a convenient shop, house, or Sub-Post Office and to arrange with the occupier for part-time switchboard attendance. This is not usually a very satisfactory solution, and the dual interests of the attendant do not favour an efficient service to the subscriber. Moreover, the revenue from such small exchanges will often not justify the provision of wakeful attendance during the evening and night periods. It is therefore necessary to arrange for "sleeping attendance" to the switchboard during the night period or, alternatively, to close down service at a predetermined hour. Under these latter conditions the loss of service during the night considerably reduces the value of the telephone for emergency purposes. In some cases it is possible to arrange for selected subscribers to be connected to the outgoing junctions from the rural exchange on a party line basis and so to provide a restricted night service for a limited number of subscribers.

Automatic switching offers a very satisfactory solution to the problem of rural areas. The very small amount of switching equipment can be installed in small unheated buildings and requires only occasional maintenance attention. No provision is made for an operator at the rural exchange, but all calls which require the services of a telephonist are routed through a manual or automanual *parent* switchboard located in a convenient nearby town. The subscribers can obtain a quick and reliable service at all times of the night and day, whilst the absence of a telephonist makes it economical to set up an exchange in areas where the provision of service on a manual basis would be extremely uneconomical.

Requirements of an Automatic System. A machine switching system must not only carry out the primary function of a telephonist in connecting one subscriber to another, but it must also provide for the many subsidiary requirements which, in a manual system, are effected orally or visually by the operator. It is desirable that the basic functions of an automatic switching system should be reviewed at this stage. Briefly the main requirements are:

1. To advise the calling subscriber when the equipment is ready for him to dial.
2. To establish connexion between the calling subscriber and the required line if the latter is not already engaged.
3. To inform the calling subscriber that the call has been satisfactorily established and that the required line is being rung. This facility is not normally provided on manual systems since the subscriber has received an acknowledgment of his call from the telephonist and in the absence of any further notification he assumes that the call is progressing satisfactorily. In an automatic system, however, the return of a signal to the calling subscriber when the required line is being rung is the first and only indication that the call is proceeding satisfactorily.
4. To ring the bell of the required line and to cut off ringing current automatically as soon as the called subscriber answers.
5. To register the call against the calling party as soon as the called party replies and conversation is established.
6. To guard any call against intrusion by other subscribers either during the setting up or release of the connexion or during the conversational period.
7. To return a distinctive signal to the calling party if the required line is engaged.
8. To return a separate and distinctive signal should the required line be out of order or be otherwise unobtainable.
9. Where a call is for a subscriber with more than one exchange line, facilities must be provided for a search to be made over all available lines before the engaged signal is returned to the calling subscriber. Similar automatic search facilities are required when the call is passed over junction routes or, in fact, at each stage of the selection where there is more than one circuit to the next stage.
10. To guard against double connexions when two calls are being set up at the same time. In manual switching systems any such dual connexions, resulting from two telephonists seizing the same circuit simultaneously, are readily rectified

by the telephonists. In an automatic system such correction is not possible and every effort must therefore be made in the design of the circuits to avoid double seizure of the same circuit by calls originating more or less concurrently.

In practically all automatic switching systems the process of connecting one subscriber to another is carried out by mechanical switches which are designed to enable a call to be extended to any one of a number of contacts or *outlets*. The subsidiary functions of signalling, testing, switching, etc., are controlled by highly ingenious arrangements of electromagnetic relays. The controlling circuits are often very complex and call for a high standard of relay performance. Part of this complexity is brought about by the economic need of utilizing various relays for different functions as the call proceeds, but apart from this factor the operating and timing characteristics of the relays in automatic switching circuits are generally much more exact than in the simpler and more straightforward circuits of manual telephony.

It has been seen in Volume I that, in a manual system, a third conductor is introduced throughout the exchange for control purposes. This third conductor is known as the sleeve circuit (or *S*-wire) and is necessary to provide for certain functions such as engaged test, removal of calling relay from the line and for other functions which cannot be carried out over the speaking conductors. In a similar manner, a third conductor known as the *private-* or *P-wire* is provided in an automatic exchange. Generally speaking, all testing, switching, metering, holding, and releasing conditions are carried out over the *P*-wire. The speaking pair is, of course, utilized for passing the signals to and from the subscriber and for the transmission of tone or other signals which are not required during the conversational period. The wires of the speaking pair in a manual system are generally known as the *A*- and *B*-wires, but by common usage these same wires in an automatic exchange are designated + and − respectively. The *A*-, *B*-, and *S*-wires of a manual exchange are therefore replaced in an automatic system by the +, −, and *P*-wires respectively.

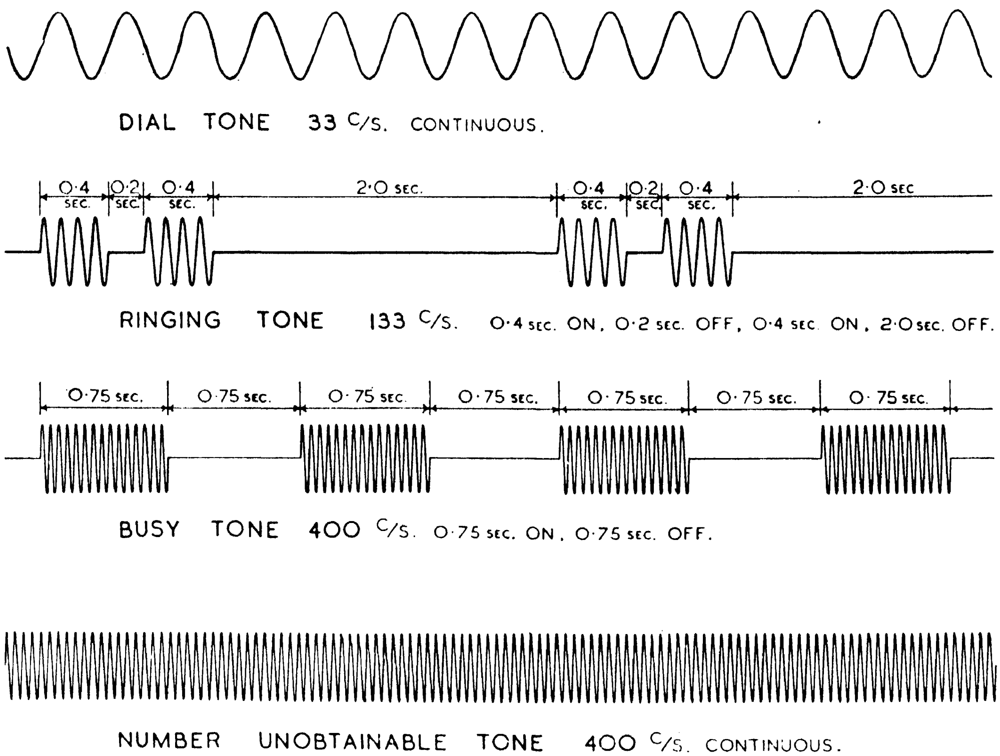


FIG. 4. STANDARD TONES OF AN AUTOMATIC SYSTEM

Tones. It has been seen above that the absence of human control in an automatic system necessitates the introduction of some means whereby a subscriber can be advised of the progress of his call. In a manual system the operator verbally informs

the subscriber when the required number is engaged or out of order and, if the time taken for the called subscriber to reply is prolonged, she also reassures the calling subscriber that she is ringing the called party. These verbal advices of a manual system are replaced in automatic telephony by a series of distinctive tones which, for obvious reasons, are maintained as uniform as possible throughout the country. The four standard tones are illustrated diagrammatically in Fig. 4 and are designated as follows:

Dial Tone. The dial tone (abbrev. D.T.) consists of a 33 c/s continuous note and, as its name implies, it is transmitted to a calling subscriber to indicate that dialling may commence. As will be seen later, a second or two may elapse between the subscriber lifting his receiver and the time that the switching equipment is ready to receive the impulse trains. It is important therefore that a subscriber should listen for dial tone before attempting to dial—even although, in the vast majority of calls, dial tone is applied before the receiver can be lifted to the ear.

Busy Tone. Busy tone (abbrev. B.T.) is a high-pitched note of 400 c/s interrupted for 0·75 second every 1·5 seconds (i.e. 0·75 second on, 0·75 second off). It is applied to the calling line whenever the junctions, the switching equipment or the required line are engaged. Whereas in a manual system the operator can differentiate between such conditions as "junctions engaged," "circuits engaged," and "subscriber engaged," the use of separate tones in an automatic system would only lead to confusion and would have very few advantages. Hence one busy tone only is employed and may signify that the call cannot be completed owing to the absence of idle plant or due to the called subscriber being engaged. It is interesting to note that, throughout the British system, once busy tone has been encountered, the tone is not withdrawn if the engaged apparatus or line becomes free whilst the caller is waiting. In all cases the call must be abandoned on receipt of busy tone and a second attempt made later.

Number Unobtainable Tone. Number unobtainable tone (abbrev. N.U.T.) is identical in pitch to busy tone (i.e. 400 c/s) but is continuous. Here again a line may be unobtainable for any one of a variety of reasons such as line out of order, line temporarily out of service, the dialling in error of a spare line, etc. The continuous 400 c/s tone thus indicates that the number dialled is unavailable due to some cause or other.

Ringing Tone. Ringing tone (abbrev. R.T.) is a tone of 133 c/s which is interrupted in the same manner as the actual ringing current which energizes the bell of a called line (i.e. 0·4 second on, 0·2 second off, 0·4 second on, 2 seconds off). Ringing tone is returned to a caller at the same time as the ringing is applied to the called line and is removed when the called party answers. For the sake of uniformity, ringing tone is also used on calls terminating on a manual switchboard where the calling signal is not of course a bell but is usually a signal lamp.

Although the standard tones present no difficulty to regular telephone users, it sometimes happens that in spite of the distinctive characteristics of each tone, casual callers sometimes become confused. It is, for example, not very unusual to find a caller listening for long periods to busy tone under

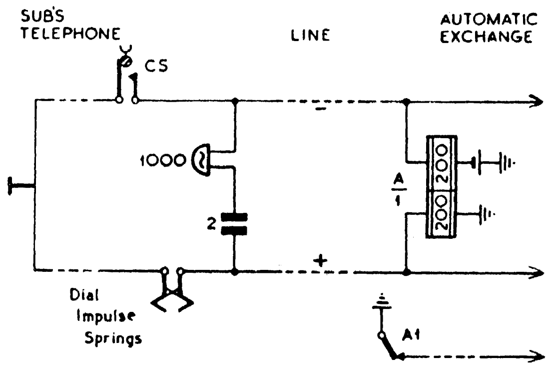


FIG. 5. SIGNALLING ELEMENTS OF AN AUTOMATIC TELEPHONE CIRCUIT

the impression that the tone received was ringing tone. It is doubtful if any appreciable improvement could be made in the character of the tones to reduce these difficulties, but the use of recorded voices to announce "Number Engaged" and "Number Unobtainable" has recently been tried out experimentally with promising results. Similarly the recorded ringing of a bell has been tried in place of the ringing tone. Sufficient experience has, however, not yet been obtained to justify the general adoption of these measures.

Signalling Conditions from an Automatic Subscriber. The basic signalling conditions from an automatic subscriber to the exchange have already been considered in some detail in Volume I. For convenience, the elements of the signalling circuits are reproduced in Fig. 5. There are altogether five simple signalling requirements:

(*a*) When a subscriber desires to make a call, the lifting of his handset allows the cradle-switch contacts *CS* to close and so to complete a d.c. loop to the exchange. This loop is utilized to seize the automatic equipment and to prepare it for the reception of impulses from the dial.

(*b*) The dial mechanism (which is illustrated in Figs. 6 and 7 and has been described fully in

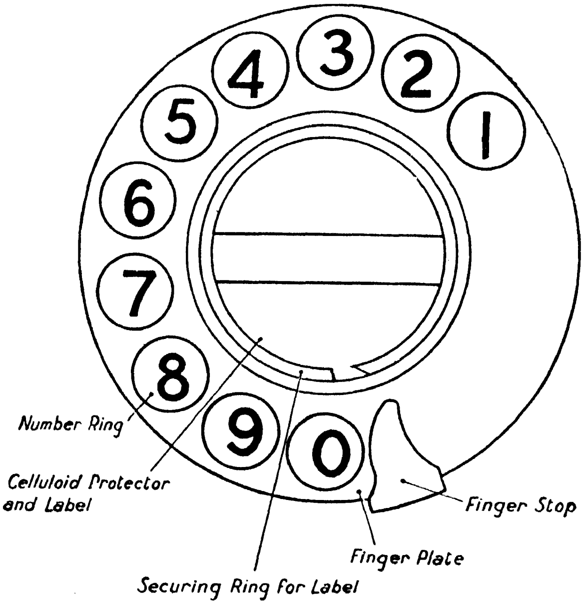


Fig. 6. Front View of Dial

Volume I) is arranged to break the loop circuit a number of times in rapid succession in accordance with the digit dialled. If, for example, the subscriber desires to dial the digit "5" he places a finger in the 5th hole of the rotatable dial plate, moves the plate round to the finger stop and withdraws his finger, so allowing the dial mechanism to restore to normal under the influence of a coiled spring. During the return of the dial from the finger stop, a train of 5 break impulses is transmitted to line. For reasons which will become apparent later, it is necessary to control both the duration and frequency of the impulses from the dial. The standard impulse has a nominal break period of 66 msec and the standard frequency is 10 I.P.S. The train of break impulses transmitted during the dialling of a number is received on an impulse accepting relay (relay *A*, Fig. 5) and a contact of this relay (*A*1) repeats the impulses to the selector control circuit. The utilization of the impulses varies with the system of switching and with the type of circuit, and will be considered in detail at a later stage.

(*c*) *After dialling and during the conversational time, the loop from the calling subscriber's telephone is utilized to provide a holding condition for the call until such time as the calling subscriber replaces his receiver.*

(*d*) At the end of the conversation the replacement of the calling subscriber's handset reopens the calling loop at the *CS* contacts, and the disconnexion of the loop is utilized as a clearing signal to release the train of automatic switches at the exchange.

(*e*) On incoming calls the attention of the called subscriber is obtained by the ringing of a magneto bell. The ringing circuit is the usual capacitor and bell in series which provides a circuit for the alternating ringing current but prevents the passage of direct current round the loop. When the subscriber answers, the circuit is looped for direct currents as described above, and this change of conditions is utilized to cut off the automatic ringing supply from the exchange and to switch the call for conversation.

Automatic telephones are, of course, of the C.B. transmission type, and the switching circuits are so arranged that, when a connexion is established, a transmission bridge is provided to both parties for the energization of their respective transmitters.

Methods of Selection. Since automatic switching was first suggested, there have been many schemes

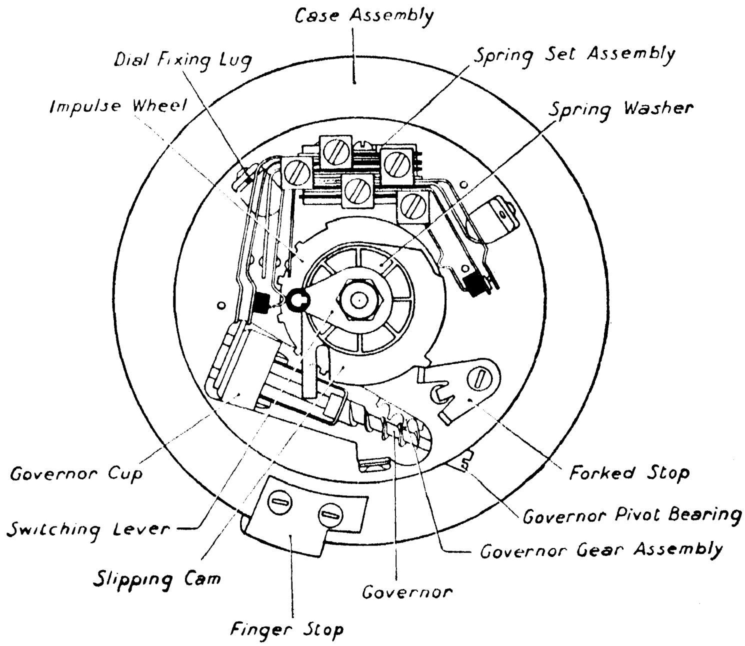


Fig. 7. Rear View of Dial

for connecting together two subscribers by means of some form of electromechanical equipment. Some schemes have been designed specially to cater for the requirements of heavily telephoned areas whilst, conversely, other methods have a particular application to the switching problems of a small exchange. In general, any automatic system is primarily designed to provide the most economical switching arrangement for the conditions under which it is to be used, but other considerations, such as reliability, the ease of tracing and rectifying faults, etc., also enter largely into the design. It is not possible to say that any one system of automatic selection is better than any other system, but, for obvious reasons, each telephone administration has endeavoured to standardize its plant to one or two methods of switching. The switch mechanisms of the various automatic systems differ widely in their general and detailed design but, apart from some of the lesser known methods, all systems of selection can be classified under one or other of the following three broad categories:

(*a*) Step-by-step selection.
(*b*) Revertive impulse control of selection.
(*c*) The marker system of control.

Details of some of the more common automatic switching systems are given later in this volume, but it is desirable at this stage to examine the three basic principles upon which the various systems have been developed.

Step-by-step Selection. This is perhaps the most obvious system of selection in which the selecting mechanism is moved forward *step-by-step* under the control of an electromagnet in conjunction with a ratchet and pawl system. The principle of a step-by-step selector is illustrated in Fig. 8. The calling subscriber's lines are connected to metallic arms or *wipers* which are made to move over a series of *bank contacts*. The called subscriber's lines are wired to the bank contacts and it is possible to connect a calling subscriber to any required line by energizing the stepping magnet the appropriate number of times. The circuit is so arranged that the break impulses from the dial are converted to positive current pulses which are applied to the stepping magnet of the selector. When, for example, digit "5" is dialled the electromagnet is energized 5 times in quick succession and the associated pawl engages the ratchet wheel to step the wipers to the 5th contact. The wipers are held in this position against the torsion of a restoring spring by a release detent which engages with the ratchet wheel.

When the calling subscriber replaces his receiver at the end of the call, the circuit is arranged to energize the release magnet which now withdraws the release detent from engagement with the ratchet and so allows the wiper assembly to return to normal under the action of the restoring spring.

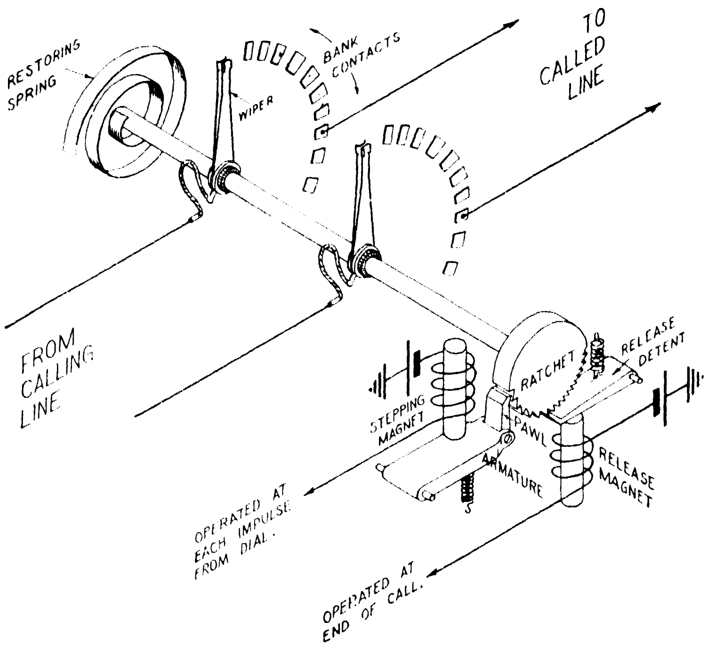


FIG. 8. PRINCIPLE OF STEP-BY-STEP SELECTION

A simple but practical mechanism of the step-by-step type is illustrated in Fig. 9. This particular mechanism is known as a *minor switch* and is not used to any great extent in modern circuits, but it is illustrative of the principles described above. Step-by-step selection and the use of mechanisms controlled by an electromagnet via a ratchet and pawl system are distinguishing features of the Strowger system of automatic telephony which is standard in the British Isles. The considerations of this volume are consequently mainly concerned with automatic switching utilizing the step-by-step principle.

Revertive Impulse Control of Selection. There are certain merits in designing a system of selection in which the wipers are power driven either from an electric motor individual to the mechanism or by coupling the wiper shaft to a system of continuously rotating shafting driven by a common

motor. In general such schemes enable selectors of larger capacity to be employed, and a more regular

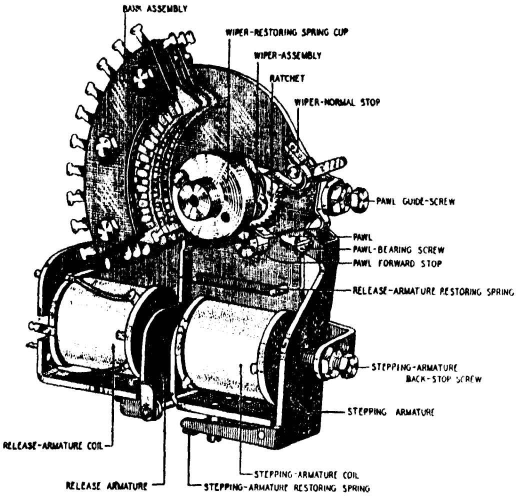


FIG. 9. A SIMPLE 10-LINE STEP-BY-STEP MECHANISM
(Minor switch)

and simpler movement of the wiper system is possible. It is clear, however, that the adoption of a power-driven selecting mechanism involves the provision of some means of arresting the motion when the required line has been reached. In the step-by-step system the position of the wipers is directly controlled by the number of pulses given to the stepping magnet, but in a power-driven system the rotation of the wipers is independent of the impulses received from the calling subscriber. A means must therefore be found of co-ordinating the movement of the wipers with the impulses received from the calling party.

In revertive impulse systems, the dial impulses from the calling subscriber are stored in a *register* or impulse counting circuit which, at the end of the impulse train, starts the rotation of the selecting wipers. Coupled to the wiper shaft is an impulsing cam which sends back (or *reverts*) an impulse to the control circuit as the wipers pass over each bank contact. These reverted impulses are counted in the control circuit, and the latter is arranged so that the drive is disconnected when the wipers reach the bank contact which gives access to the line required. If, for example, the digit "4" is dialled, the incoming impulse counting circuit sets up conditions which indicate that the 4th contact is required. As the wipers rotate, impulses are reverted to the control circuit until it is known that the 4th contact has been reached. The wiper drive is now disconnected and the circuit is switched for conversation. The principle is shown diagrammatically in Fig. 10. In this particular case an electromagnetic clutch is used to connect the wiper spindle to a system of continuously rotating shafting. When the required contact has been reached the clutch electromagnet is disconnected and the movement of the wipers is arrested. There are many variations of this principle, some of which utilize individual motor drive and others (notably the panel system) where the wipers move in a vertical direction instead of rotating as shown. The characteristic of all revertive impulse systems is, however, the method of arresting the wipers by a system of impulses fed back to the controlling circuit as the wiper movement proceeds.

Marker Control Systems. The marker system is an important alternative to the revertive impulse system for the control of selecting mechanisms which are either power driven or are otherwise rotated independently of the incoming impulses. As before, the impulses from the calling sub-

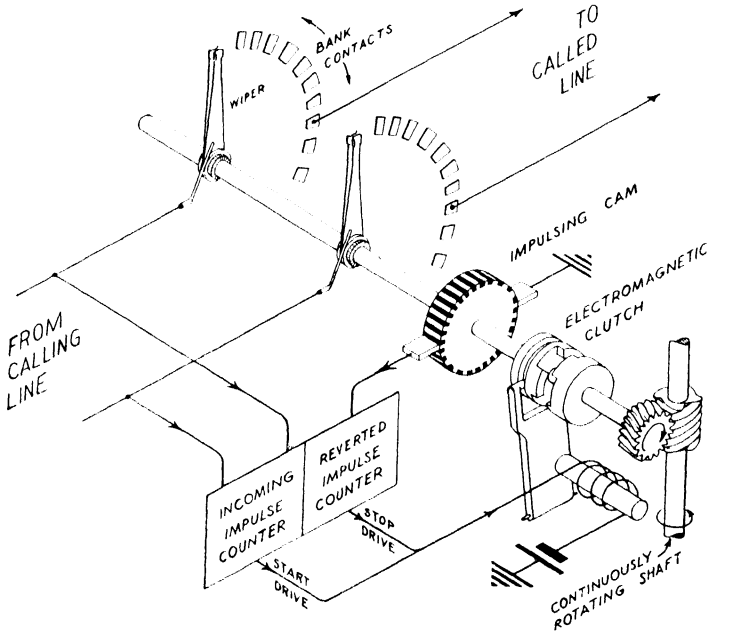


FIG. 10. PRINCIPLE OF REVERTIVE IMPULSE SYSTEMS

scriber's dial are stored in a suitable counting circuit and, at the completion of impulsing, a

marking condition is applied to the appropriate contact of the mechanism bank (Fig. 11). The circuit is so arranged that the wipers are moved under independent control until such time as they reach the marked contact. A circuit is now completed for a drive-cutting relay which operates to the marking condition and arrests the movement of the wipers.

There are many variations of this principle of marking. In one system (the *relay system*) selecting mechanisms are eliminated altogether and the marking condition is made to energize a system of relays which connects the called subscriber to the common connecting circuit seized by the calling party. In another system, the more usual type of mechanism is replaced by a *crossbar switch* which provides facilities for connecting, say, ten lines with any one of twenty other circuits by the operation of two electromagnets. The Standard Telephones & Cables Bypath system and Messrs. Siemens No. 17 system are typical examples of marker control. Both systems are based on unidirectional mechanisms, but whereas the bypath mechanisms are driven by an electromagnet via a ratchet and pawl system, the Siemens No. 17 selectors incorporate a simple electric motor geared to the wiper shaft.

Trunking Diagrams. The above principles illustrate the more important methods of automatic switching, but it will be appreciated that, apart from the actual design of the selecting mechanisms and the details of the controlling circuits, a number of the problems of telephony is concerned with the method of *interconnecting* the mechanisms to obtain the most efficient switching arrangement, and hence the most economic provision of plant. For such considerations the ordinary schematic circuit diagram is unnecessary and is merely confusing. A system of simple straight line diagrams, known as *trunking diagrams*, has therefore been evolved. These diagrams show the selecting mechanisms in simple diagrammatic form and single lines may represent a complete group of conductors leading to and from the mechanism. The main symbols used on trunking diagrams are illustrated in Volume I, and are introduced in the following paragraphs.

Ten-line Step-by-step Exchange. An elementary 10-line exchange utilizing step-by-step mechanisms can be designed on the lines of Fig. 12. Each telephone is terminated at the exchange on a relay group which contains all the necessary apparatus for the control of the switch mechanisms and for the various subsidiary functions, i.e. testing, switching, return of tones, etc. A 10-point step-by-step mechanism of the type illustrated in Fig. 9 is also provided on the basis of one per line. Three contacts are provided for each rotary position of the switch to cater for the two speaking conductors and the control or *P*-wire. These contacts are commoned to similar contacts on each of the ten switches serving the subscribers. Thus any subscriber can obtain access to any other subscriber in the group of ten by dialling the number of the line required.

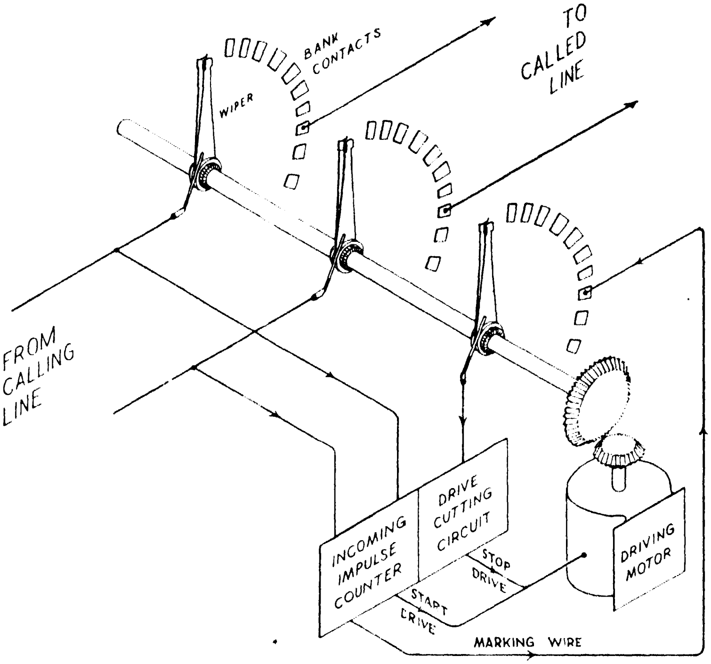


FIG. 11. PRINCIPLE OF MARKER SYSTEMS

Whilst this elementary conception would provide automatic service between the ten subscribers of the exchange, the economics of the scheme leave much to be desired. It is more than probable that on an exchange of this size there will not be more than, say, two or three simultaneous conversations at the busiest part of the day. Hence, under the best conditions at least seven or eight of the selecting mechanisms must be idle. The method of overcoming this obvious disability is discussed later, and for the time being it is interesting to see how this elementary conception can be developed to cater for exchanges of more than 10 lines.

Decimal Dialling. If the number of subscribers on the hypothetical exchange increases from 10 to, say, 15, then some revision of the trunking arrangements shown in Fig. 12 will be required. The standard dial is capable of sending out a maximum of 10 impulses in one train, but there are no serious difficulties in designing a dial with 15 finger holes and capable of sending out a train of up to 15 impulses. Such a dial would, of course, be a little larger and would perhaps not be so easy to manipulate, but the proposition is not entirely impracticable. Similarly the selectors at the exchange can be designed to provide 15 instead of 10 outlets, and the trunking arrangements would be fundamentally similar to those of the 10-line exchange.

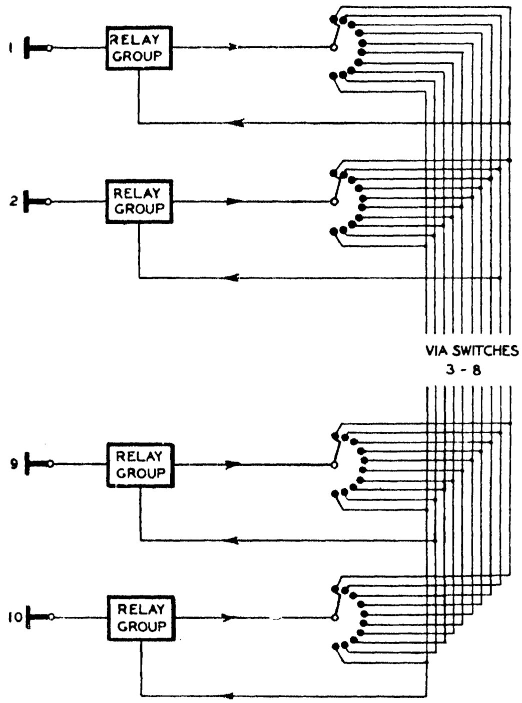


FIG. 12. ELEMENTARY 10-LINE AUTOMATIC EXCHANGE (Step-by-step system)

Whilst the above method of increasing the capacity of an exchange is practicable up to, say, 15 or even 20 lines, it is an impossible scheme if the number of subscribers is appreciably greater than this number. If, for example, there are 100 subscribers, each subscriber would require a dial capable of sending out trains of from 1 to 100 impulses. Apart from the impracticability of designing a dial of suitable size for associating with the telephone, the time necessary to send out 100 impulses is intolerable in a commercial system. On the other hand, there are no real difficulties in designing a selector with 100 outlets. Selectors of greater capacity are, in fact, in common use in automatic systems.

The only practicable method of signalling when the number required is appreciably greater than 10 is to adopt the ordinary system of decimal notation involving a *units* digit, a *tens* digit, a *hundreds* digit, and, if necessary, a *thousands* digit. This enables the standard 10-hole dial to be used for all calls irrespective of the size of the exchange. Thus, to call number 54, the calling subscriber would dial first the digit 5 followed by a second digit 4. Similarly, in a large exchange the subscriber might be required to dial 4 or even 5 digits. This system of dialling on a *decimal basis* is now universal for all systems of automatic telephony, but the method of using the several impulse trains to establish connexion to the required line varies considerably in the different switching systems.

Decimal Selection. The most obvious way of selecting any particular line in an automatic switching system is to utilize a process of decimal selection provided by the consecutive digits from the subscriber's dial. A group of, say, 100 subscribers' lines may be considered as comprising 10 groups each of 10 lines. Similarly, a block of 1000 subscribers may be subdivided into 10 groups each of 100 lines, each group of 100 lines again being divided into 10 groups of 10 lines each. This process of analysis is applicable to numbers of any magnitude, and it is possible to select any particular number by a process of selecting first the group of the largest unit, then the group of the next largest unit, and so on until by narrowing down the process the individual line is finally reached.

In a 10 000-line exchange, for example, the first digit can be used to actuate a mechanism which will select the particular 1000's group required. The call can then be switched so that the second digit operates a second mechanism which will select the required 100's group. The third digit can operate a further mechanism which will select a particular one of the 10 groups which comprise the chosen 100's block, whilst, finally, the 4th digit can operate a mechanism to select the particular line required in the selected group of 10. The search for a given line thus proceeds stage by stage and employs a system of progressive elimination based upon a decimal process of selection. Decimal selection is the fundamental basis of the Strowger system of automatic telephony.

Non-decimal Selection. Although the signals transmitted by a subscriber's dial are on a decimal

basis, it does not follow that the actual process of selection should also be on a decimal basis. Quite a large number of successful automatic systems do in fact employ a non-decimal process of selection. In a 100-line exchange the process of decimal selection utilizes the first digit dialled by the subscriber to select a particular group of 10 lines, whilst a second mechanism responds to the second digit to select the required line in the chosen group of 10. With non-decimal selection it is possible to have a single mechanism which gives access to the whole group of 100 lines and to utilize the digits dialled by the subscriber to determine the position to which the selector should be stepped. It is clear that with such a system the impulses from the calling subscriber's dial cannot be used directly to control the selecting mechanism. The dialled impulses must be recorded in a special circuit and when the final impulse train has been received the position to which the selector mechanism must be moved can be determined.

Fundamentally, non-decimal selection can be employed with practically every type of switch mechanism, but the revertive impulse and marker principles are particularly suitable for this method of control. It is theoretically possible, for example, to utilize the marker principle illustrated in Fig. 11, in conjunction with, say, 500 or even 1000 point selector mechanisms. The 3 or 4 digits received from the subscriber's dial are routed to an incoming impulse counter (or register) which can be arranged to mark any desired bank contact of a large selector mechanism. At the same time the mechanism can be set in motion and when the desired contact is reached the electrical marking condition can arrest further motion and switch the calling subscriber to the required line. The same method of selection can be and is used in conjunction with mechanisms controlled by the revertive impulse system (Fig. 10). The limiting factor in each case is the time taken to reach the required line. It is for this reason that step-by-step mechanisms are not normally utilized in a system employing non-decimal selection. Even on power- or motor-driven systems of the marker or revertive impulse type it is common practice to limit the *hunting time* by the provision of multiple wipers which can be switched into service as required to minimize the number of contacts over which the mechanism is required to search.

Numbering of Subscribers' Lines. It is interesting at this stage to compare the system of numbering subscribers' lines in an automatic exchange with the arrangements for a manual system. In a manual exchange of, say, 5000 lines capacity, the subscribers' numbers may contain single digits, 2 digits, 3 digits, or 4 digits. A request for subscriber "21," for example, indicates to the operator the 21st line on the exchange, i.e. the 21st subscriber in the first block of 100. The telephonist is in the position of being able to interpret the number as a whole and hence there is no possibility of confusion with a request for a number in, say, the 2100 group. In an automatic system, on the other hand, each digit is dialled consecutively by the subscriber and the automatic equipment has no means of ascertaining when the dialling is complete except by counting the number of impulse trains received. It is clear that if on a 5000-line exchange the number 21 is permitted, then it would not be possible to utilize the 3-digit numbers 210 to 219 or the 4-digit numbers 2100 to 2199. Similarly, if single-digit numbers were permitted it would not be practicable to have 2-digit, 3-digit, or 4-digit numbers commencing with the same initial digit. It is for this reason that, apart from certain exceptions, the subscribers' numbers on any one exchange have the same total number of digits. In a 100-line exchange all the numbers have 2 digits, whilst on a 10 000-line exchange each subscriber's number contains 4 digits.

Whilst the above is true for the numbering of subscribers, it is common practice to provide single- or 2-digit codes for access to special points such as, for example, "0" for operator, "91" for inquiries, and so on. Such codes are used, however, only when the volume of traffic is sufficiently great to justify the consequent loss in the available subscribers' numbering range. The general use of the single digit "0" for obtaining access to the operator precludes the allocation of "0" as the *initial* digit of a subscriber's number. The digit 0, nevertheless, consists of a train of 10 impulses and, so far as the automatic equipment is concerned, it is one of the 10 available numbers for all except the first digit. Thus, any particular group of 100 lines includes the numbers 01, 02, 03, etc., to 09 in addition to the more obvious numbers 10, 11, and so on. Similarly, in a given block of 1000 lines there will be subscribers' numbers such as 001, 002, . . . 099.

Decimal Selection Using Ten-point Uniselectors. An elementary switching system utilizing 10-point uniselectors and arranged for selection on a decimal basis is illustrated in Fig. 13. Each subscriber's line is terminated on a 10-point uniselector which, by responding to the first digit, selects one out of 10 groups. During the pause after the first digit, the line is switched through to a second uniselector which serves the 10 lines of the selected group. The second digit from the dial now steps the final uniselector to choose the required line from the chosen

group of 10. If, for example, the digits 56 are dialled, the first uniselector will step to the 5th contact in response to the first digit, whilst the

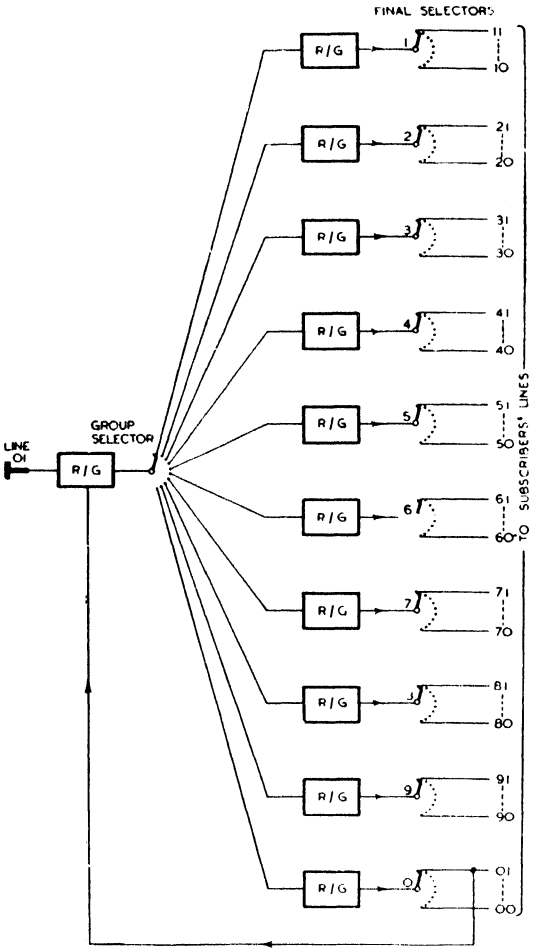


FIG. 13. 100-LINE EXCHANGE USING 10-POINT UNISELECTORS

second uniselector steps to the 6th contact to select line No. 56. Two ranks of switches are now required—*group selectors* to receive the first or 10's digit and *final selectors* to choose the number in the selected group of 10.

The principle of decimal selection can be developed for areas with more than 100 subscribers by the inclusion of one or more additional group selector stages. In a 1000-line exchange, for example, there would be 2 stages of group selection to determine, firstly, the 100's group and then the 10's group required. Similarly a 10 000-line exchange would require 3 group selector stages. *Whilst there is no objection technically to this* method of selection, the number of uniselectors required grows enormously as the size of the exchange increases. In the simple 10-line exchange of Fig. 12 a total of 10 uniselectors only are required. In the 100-line exchange, there are 11 uniselectors per line, i.e. a total of 1100 uniselectors for the exchange. If the system is increased to 1000 lines capacity the number of mechanisms *per line* is increased to 111 which gives a total of 111 000 mechanisms for the exchange. The use of uniselectors for each successive stage of selection does therefore soon become impracticable on economic grounds and it is necessary to consider some alternative method of accomplishing the same decimal selection with a more reasonable quantity of equipment.

The Two-motion Selector. If it were possible to obtain a simple selector capable of performing all the functions of the 11 uniselectors required per line in a 100-line exchange, then, providing that the cost of this selector is less than the total cost of

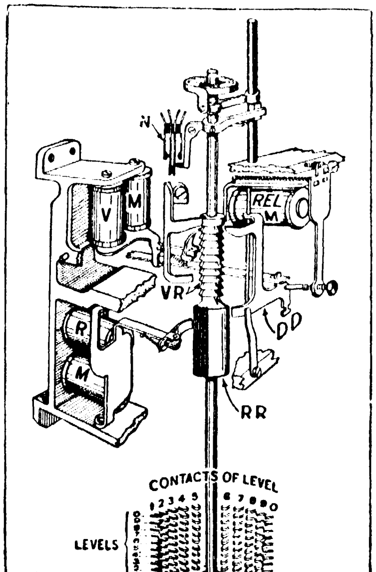
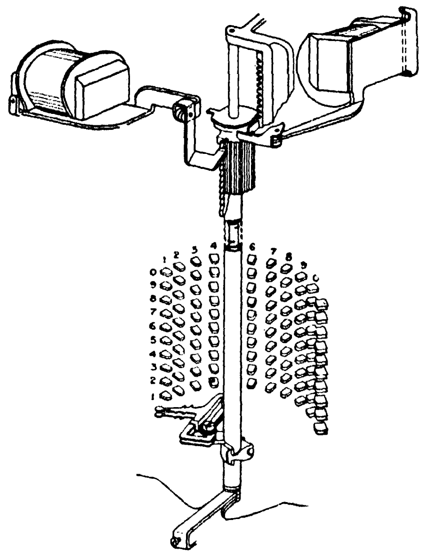
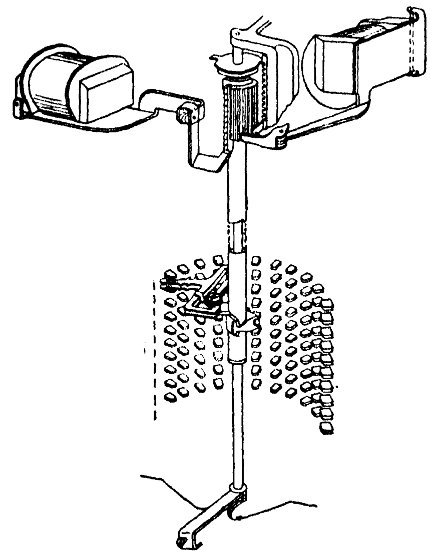


FIG. 14. PRINCIPLE OF 2-MOTION SELECTOR (3-magnet type)

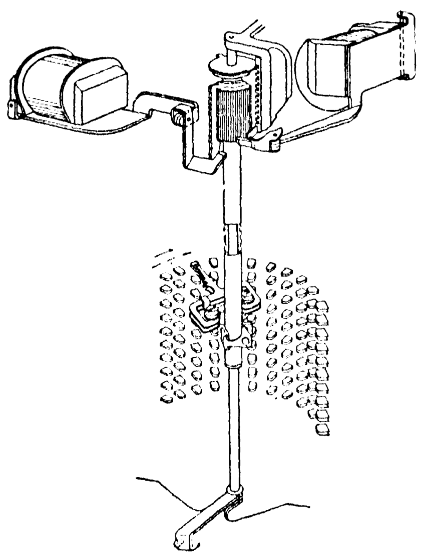
the 11 uniselectors, some overall decrease in the cost of the exchange is possible. If the contact banks of the 10 final selectors (Fig. 13) were arranged horizontally and mounted one on top of the other, the complete assembly would give access



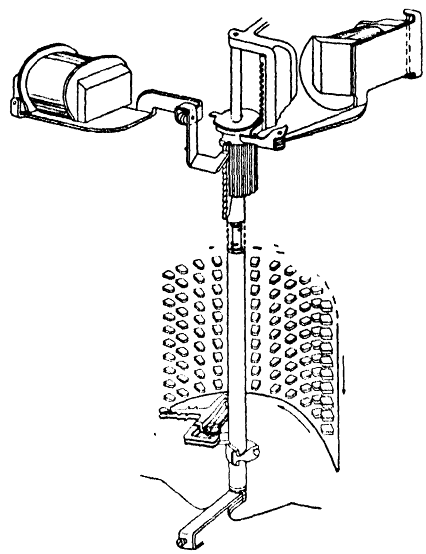
Wiper carriage in normal position.



Wipers stepped to tenth level.



Wipers stepped to third contacts on tenth level.



Release action.

FIG. 15. ACTION OF 2000 TYPE (2-MAGNET) 2-MOTION SELECTOR

to 100 subscribers' lines. If now the mechanism could be designed so that the wipers were stepped vertically to select the particular 10's group required and then horizontally to choose the number required in that group, such a mechanism would replace the group selector and the 10 final selectors of the 100-line uniselector exchange. A selecting

Levels	Contacts 1	2	3	4	5	6	7	8	9	0
0	01	02	03	04	05	06	07	08	09	00
9	91	92	93	94	95	96	97	98	99	90
8	81	82	83	84	85	86	87	88	89	80
7	71	72	73	74	75	76	77	78	79	70
6	61	62	63	64	65	66	67	68	69	60
5	51	52	53	54	55	56	57	58	59	50
4	41	42	43	44	45	46	47	48	49	40
3	31	32	33	34	35	36	37	38	39	30
2	21	22	23	24	25	26	27	28	29	20
1	11	12	13	14	15	16	17	18	19	10

FIG. 16. NUMBERING OF 2-MOTION SELECTOR BANK CONTACTS

mechanism in which the wipers move consecutively in two planes at right angles is known as a *2-motion selector* and such selectors are the characteristic feature of the Strowger system.

The principal elements of a 2-motion step-by-step selector mechanism are illustrated in Fig. 14. The bank contacts of the mechanism are arranged as 10 layers or *levels* each of 10 contacts. Access to any particular contact can be obtained by moving the wiper shaft vertically to the level required and then rotating the wipers to the desired contact in that level. The first impulse train from the subscriber's dial operates the vertical magnet (*VM*) during each break impulse. A pawl attached to the armature assembly of the vertical magnet engages with a vertical ratchet (*VR*) to raise the wiper shaft one step at each operation of the vertical magnet. At the first vertical step a detent (*DD*) engages with the vertical ratchet and so prevents the wiper shaft from falling after each consecutive vertical step. The second impulse train from the subscriber's dial is directed to the rotary magnet (*RM*) of the switch mechanism. The rotary pawl associated with the rotary magnet armature engages with a rotary ratchet (*RR*) to move the wiper shaft against the torsion of a helical spring. The lower portion of the detent (*DD*) engages with the rotary ratchet to retain the wipers after each operation of the rotary magnet. At the end of the call, the energization of the release magnet withdraws the detent from the vertical and rotary ratchets to allow the mechanism to restore to normal; the mechanism being so arranged that the wipers are moved clear of the bank contacts before they are allowed to restore vertically.

In recent years a new type of 2-motion selector mechanism has been introduced (2000 type). In principle the new mechanism is very similar to the older design with one important difference. The release magnet has been eliminated and restoration of the mechanism is effected by continuing the rotary motion to the 12th rotary position and then allowing the wiper carriage to release vertically (and then horizontally) under the action of an internal coiled spring. Fig. 15 shows how the wipers are stepped to, and subsequently released from, the 3rd rotary contact of the 10th level. The 2000 type selector is sometimes designated a *two-magnet* mechanism to distinguish from the earlier *three-magnet* selectors.

Since the wipers of a 2-motion selector are positioned by the impulses received from the subscriber, it follows that the bank contacts of such a selector must be numbered to correspond with the digits necessary to reach each contact. The numbering of a standard 100-contact bank is shown in Fig. 16. It should be noted that the first level commences with 11 and ends with 10, whilst contact numbers 01 to 00 occupy the tenth level.

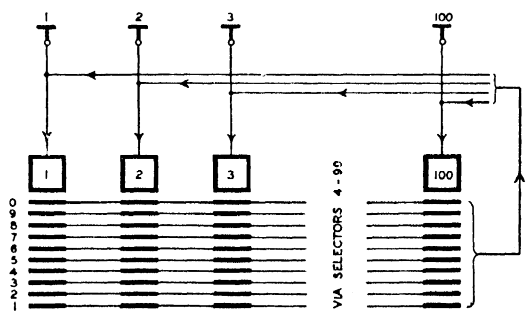


FIG. 17. ELEMENTARY 100-LINE EXCHANGE WITH 2-MOTION SELECTORS

100-line Exchange Using 2-motion Selectors. A 100-line exchange using 2-motion selectors is shown diagrammatically in Fig. 17. In this illustration the standard trunking diagram symbol for a 2-motion selector has been introduced. It consists of a square to represent the relay group and controlling mechanism with ten thick horizontal lines beneath it to represent the ten levels of contacts.

The multiple wiring connecting together the bank contacts of adjacent selectors is indicated by thinner horizontal lines between the levels of the individual selectors.

It will be noted that one 2-motion selector has been shown per subscriber, the 100 outlets of all selectors being commoned together. Thus, a total of 100 2-motion selectors is required and, although some reduction in the overall cost of the exchange has been effected by the introduction of 2-motion selectors, the arrangements are still far from being efficient. The theoretical maximum number of simultaneous calls which it is possible to have in a 100-line exchange is 50. To attain this figure, all of the subscribers on the exchange must be speaking simultaneously. Even under these extreme and impracticable conditions, 50 per cent of the total switching plant must be idle at any one time. In practice, the conditions just postulated (i.e. 50 simultaneous calls on a 100-line exchange) are extremely unlikely to occur. Records taken of the traffic show that, even in a busy exchange, the maximum number of simultaneous conversations per 100 subscribers is only in the order of from 10 to 15. Thus, from a practical point of view, the trunking arrangements shown in Fig. 17 are such that not more than, say, 15 of the 100 available selectors are in use *at the busiest part of the day*, the remaining 85 or so being idle. The efficiency is, of course, much worse during the slacker periods.

Common Switching Equipment. In the switching schemes so far described, an automatic selector has been provided for each subscriber's line. It has been seen that such a basis of provision is extremely costly and in most cases results in a large proportion of the switching equipment being idle even during the busy part of the day. The fundamental requirement of an automatic system is that there shall be a sufficient number of selectors to carry the anticipated maximum volume of traffic. If, for example, in the 100-line exchange already described the maximum number of simultaneous conversations is, say, 10, then all requirements can be met by the provision of ten 2-motion selectors. The provision of switching equipment on a *traffic* basis instead of individual equipment per subscriber does, however, require that arrangements be made to connect a free selector from the common group to any subscriber's line whenever a call is required. It is, of course, an elementary condition that the savings resulting from placing the selectors in a common pool should be greater than the cost of the equipment necessary to associate the subscriber's line with a selector. In normal circumstances this fundamental object is readily realized, but there are many alternative methods of associating a calling subscriber's line with a free selector mechanism. In general, the method adopted in any particular circumstances is determined by the following considerations:

(*a*) The total cost of the selectors and of the equipment for associating the calling subscribers with these selectors should be a minimum. (As will be seen later the method of connecting a subscriber's line to the switching equipment has an appreciable influence upon the number of selectors required.)

(*b*) The time between the subscriber lifting his receiver and the seizure of a selector (i.e. the time taken before dial tone can be returned to the subscriber) should not be excessive.

(*c*) The system must not unduly complicate the maintenance of the equipment and must provide a ready means of tracing connexions.

The placing of the main switching equipment into a common pool to which any subscriber can be given access is comparable to the condition in a manual exchange where the supervisory relays, transmission bridge, the testing circuit, and the speaking and ringing keys are placed in cord circuits common to the position. The provision of a 2-motion selector per subscriber's line (as in Fig. 15) is somewhat analogous to the provision of a cord circuit and a complete subscriber's multiple for each line on the exchange. Such a scheme would be quite impracticable. In a manual system the method of associating a calling subscriber's line with a free cord circuit on the operator's position is the manual insertion of the answering plug into the answering jack of the calling line. In automatic telephony there are two main methods of connecting the switching mechanism to the calling line. The first method is by the use of *selector hunters* (or subscribers' uniselectors). In this system, one comparatively inexpensive rotary switch of the uniselector type is provided per line and when the subscriber lifts his receiver the uniselector automatically rotates to find a free selector in the common group. The second method is to connect the subscribers' lines to the bank contacts of uniselectors or 2-motion selectors which, when the subscriber lifts his receiver, hunt for the calling line and extend it to the first selector of the switching train. The mechanisms which search for the calling subscriber's line are known as *linefinders*. The field of application and the limitations of the two methods will be seen later.

100-line Exchange with Subscribers' Uniselectors. The trunking arrangements of a 100-line exchange using subscribers' uniselectors are shown in Fig. 18. Each subscriber is now provided with a uniselector which has ten sets of contacts or outlets. These

outlets are in turn connected to ten numerical selectors which are assumed to be sufficient for the normal peak traffic of the exchange. The banks of all the uniselectors are commoned together so that all subscribers have access to each of the ten available selectors. Associated with each uniselector is a small group of two relays which controls the automatic hunting of the uniselector and the subsequent switching through to the numerical selector. The uniselector commences to hunt immediately the subscriber lifts his receiver, and the circuits are so arranged that dial tone is not connected until the uniselector has found and seized a free 2-motion selector.

The time taken for dial tone to be returned to the calling subscriber depends, of course, on the number of steps which the uniselector must take to find a free selector. This time is rarely in excess of one second in practice unless all selectors are engaged when a call is originated. Under these conditions the uniselector will continue to rotate until either a selector becomes free or the call is abandoned. Fig. 19 shows the conditions of Fig. 18 in a much simpler manner and is the usual method of indicating subscribers' uniselectors on a trunking diagram. It will be noted that, for simplicity, the bank contacts of the subscribers' uniselectors are represented by a continuous arc which is connected by a single line to the 2-motion selector. In a simplified diagram of this type it should be appreciated that the trunking arrangements are purely diagrammatic and that there are in fact a number of outlets from a large number of subscribers' uniselectors connected to a whole group of 2-motion selectors.

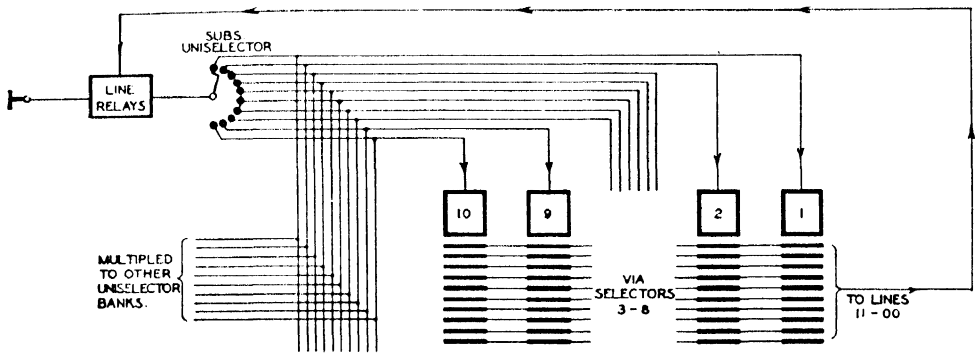


FIG. 18. 100-LINE EXCHANGE WITH SUBSCRIBERS' UNISELECTORS

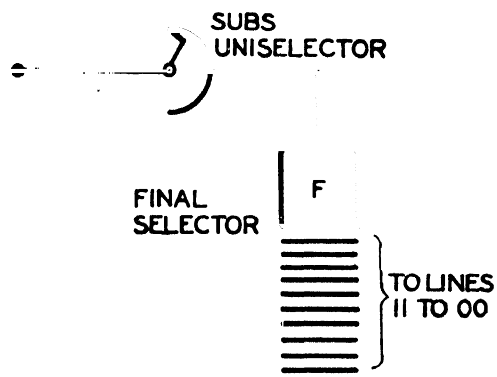


FIG. 19. SIMPLIFIED TRUNKING DIAGRAM OF FIG. 18

It is interesting to compare the equipment required when subscribers' uniselectors are employed with the more elementary scheme (Fig. 17) where one 2-motion selector was required per subscriber. The net result of introducing subscribers' uniselectors on the simple 100-line exchange is a saving of ninety 2-motion selectors at the expense of an additional one hundred uniselectors. The cost of a uniselector is much less than that of a 2-motion selector and on this account alone subscribers' uniselectors are amply justified. The savings are not, however, limited to the cost of the switches. It will be remembered that with each 2-motion selector a large relay group is necessary to control the stepping of the mechanism, to test and ring the called line, to provide a transmission bridge, and so on. Hence, in addition to the saving in selectors, one hundred 2-relay groups now replace the ninety much more complex relay groups of the 2-motion selectors. Moreover, the use of uniselectors reduces the amount of rack space required and consequently permits of a reduction in the accommodation required to house the equipment.

100-line Exchange with Linefinders. It is clear from a further examination of Fig. 19 that, although considerable economies of 2-motion selectors have been made by the provision of subscribers' uniselectors, the uniselectors themselves must of necessity be idle for a large part of the day. If the

originated traffic per subscriber is high, the provision of a uniselector per line is perhaps warrantable although, even on a fairly busy exchange, the average time for which each uniselector is in use will rarely exceed more than a few minutes during each day. In a small exchange with little traffic, the efficiency is so low that an alternative means of associating the subscriber's line with the numerical are considerable, then linefinders may become more expensive than subscribers' uniselectors.

Fig. 20 illustrates a simple linefinder scheme applied to the hypothetical 100-line exchange already considered. As before, ten 2-motion selectors are provided to receive the impulses from the subscriber's dial. A linefinder is associated with each 2-motion selector and since there are a hundred

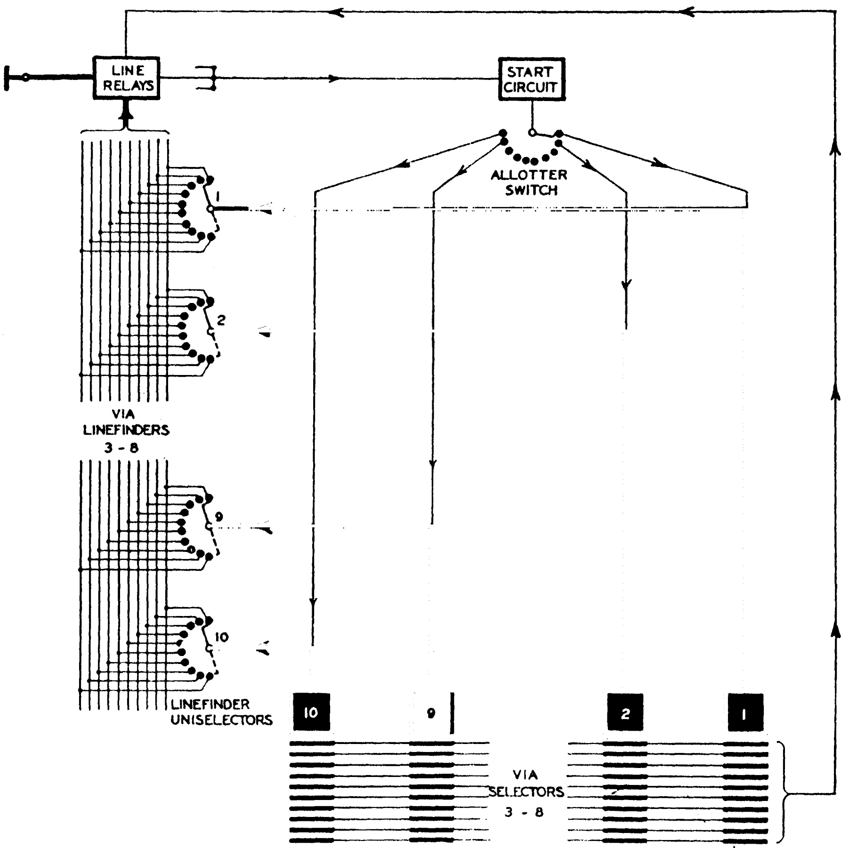


FIG. 20. 100-LINE EXCHANGE WITH UNISELECTOR TYPE LINEFINDERS

selectors is desirable. In these circumstances the alternative method of utilizing linefinders instead of subscribers' uniselectors may be more economical. Although a linefinder is usually somewhat more expensive than a subscriber's uniselector, linefinders are provided on the basis of one per 1st selector, whereas subscribers' uniselectors are on the basis of one per line. Since the number of 1st selectors is dependent upon the volume of traffic it follows that, where the traffic is light, the cost of linefinders is low but if, on the other hand, the volume of traffic and the number of 1st selectors lines on the exchange, the simple solution is to provide a hundred outlets on the linefinder banks. The outlets of the linefinders are multipled together and give access to all the subscribers on the exchange. A means must now be found whereby, when a subscriber lifts his receiver, the linefinder associated with a free 2-motion selector can be made to hunt for the calling line. In some very small exchanges the circuit is arranged so that all free linefinders commence to hunt for the calling condition on receipt of a start signal from the subscriber's line relay. When one linefinder seizes the calling

line, the start condition is broken down and the remaining linefinders then cease to hunt. This scheme cannot, however, be applied to a large exchange. Although the simultaneous hunting of two or three linefinders may be beneficial in reducing the time necessary to associate a calling line with a 1st selector, it is inadvisable to allow a large number of linefinders to search for a single calling condition. In most practical linefinder schemes it is usual to introduce an *allotter* switch in the start circuit of the linefinder. The circuit arrangements are such that the wipers of the allotter switch (Fig. 20)

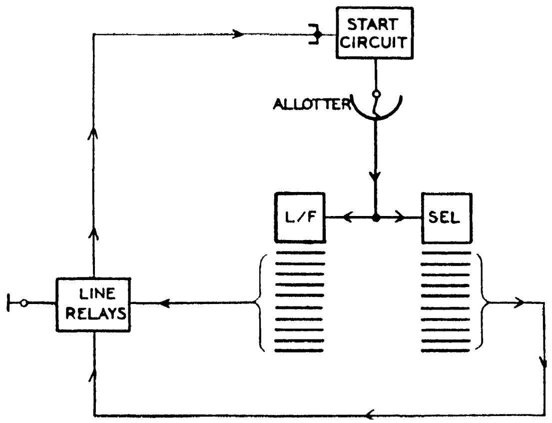


FIG. 21. 100-LINE EXCHANGE WITH 2-MOTION SELECTORS USED AS LINEFINDERS

normally stand on the contacts connected to a free 2-motion selector. When a subscriber lifts his receiver the start signal from his line relay is passed to a common start circuit and thence via the allotter switch to a particular linefinder which then commences to hunt for the calling line. As soon as the calling line is found, the allotter switch steps to the next free 1st selector in readiness for subsequent calls. The allotter circuit in effect selects in advance the 1st selector and linefinder to be used on the next call.

It has already been stated that the method of connecting a subscriber's line to a 1st selector must ensure that there is no abnormal delay in the return of dial tone to the calling party. If only one start circuit and allotter switch is provided, then there is a possibility of prolonged delay if a second subscriber should originate a call whilst search is in progress for a preceding call. Moreover, the common start circuit and allotter switch form a key link in the switching system and any failure of this circuit would result in complete breakdown. It is therefore common practice to provide two or three allotter circuits so that if several calls originate in rapid succession, or if one allotter switch is faulty, the service will not be adversely affected.

The arrangement of Fig. 20 has one serious limitation. In the extreme case a linefinder may have to make 99 steps to find the calling line and, unless a mechanism of very high hunting speed is available, the time taken for dial tone to be given to the calling subscriber may be excessive for commercial requirements. A uniselector linefinder is quite satisfactory for a maximum of, say, 25 or even 50 lines, but if the number of subscribers exceeds this figure, it is necessary either to divide the subscribers into small groups or, alternatively, to utilize a 2-motion selector for the linefinder. The division of the subscribers' lines into small groups of, say, 25 lines is very uneconomical for reasons which will be apparent later, and it is therefore usual to adopt 2-motion type selectors whenever the total number of subscribers is appreciable.

Fig. 21 shows, in trunking diagram form, a simple scheme utilizing 2-motion linefinders. When the subscriber lifts his receiver the operation of the line relay forwards a signal over the start wire to a common start circuit. The allotter associated with the start circuit is normally standing on contacts which give access to a free selector and linefinder. The start condition is repeated from the start circuit to cause the linefinder mechanism to hunt vertically until the wipers reach a marked level. The vertical hunting is then stopped and rotary hunting commences to find a particular marked contact on that level. Thus, in the extreme case, not more than 20 steps (ten vertical and ten rotary) are required to find any one line in a group of a hundred. It should be clearly understood that when a 2-motion selector is used as a linefinder, the circuit is arranged so that both vertical and rotary stepping are automatic and do not require impulses from the subscriber's dial. As in the previous circuit, when the linefinder switches to the calling subscriber's line, the start condition is removed and the allotter steps on to the next free linefinder in readiness for further calls.

Compare for a moment the equipment requirements of a 100-line exchange using linefinders with one employing uniselectors. It has been seen that under the latter conditions 100 uniselectors are required, irrespective of the amount of traffic originated by the subscribers. In the linefinder scheme (with 2-motion selectors utilized as linefinders) there is a minimum requirement of 100 small relay groups for the termination of the subscribers' lines and two or perhaps three allotter switches and start circuits. In addition, some 10 or so linefinders of the 2-motion type are required together with the same number of numerical selectors. The number

of linefinders and the number of numerical selectors are, of course, determined by the volume of traffic. For low values of traffic the linefinder scheme is obviously the more economical. As the amount of traffic increases so does the cost of the linefinders, until a point is reached beyond which the total cost of linefinders, allotters and subscribers' relay groups exceeds the cost of one uniselector circuit per subscriber. Thus it may be stated that, in general, the use of linefinders is more economical when the traffic is low, but that subscribers' uniselectors are preferable if the traffic is heavy. In the British Standard System linefinders of the uniselector type are used in small rural exchanges with a capacity of up to 100 subscribers' lines. In the somewhat larger urban exchanges with provision for up to 800 lines, linefinders of the 2-motion selector type are used. In all the larger exchanges 24-outlet subscribers' uniselectors are provided as the standard practice.

1000-line Exchange. So far the principle of the step-by-step system as applied to a 100-line exchange has been described. Such an exchange is frequently spoken of as a 2-digit exchange because all the numbers allotted to the subscribers must have 2 digits. For a 1000-line exchange the subscribers' numbers must have 3 digits, and the exchange may be referred to as a 3-digit exchange in consequence. The numbers on such an exchange range from 000 to 999, and the process of selection used in the segregation of a particular line must, therefore, occupy three stages.

Where 2-motion selectors are used, a 1000-line exchange may be considered as comprising 10 separate groups of 2-motion selectors, each group giving access to 100 lines. The particular 100-line group required is determined by the 1st digit, which must be used to operate an additional selector, the function of which is to route the call to the appropriate 100's group. When, as in this case, there is more than one stage of selection, it is usual to describe the switches either as *group selectors* or as *final selectors.* When there is more than one stage of group selection, then the switches in each stage are designated 1st group selectors, 2nd group selectors, and so on.

We have seen that, to obtain the maximum efficiency, automatic switches should, as far as possible, be provided on the basis of the maximum traffic to be carried. Thus, for economic reasons, the number of final selectors in each group must be limited to the maximum number of simultaneous calls to that group, and, similarly, the total number of group selectors should not exceed the total number of simultaneous calls passing through that stage. This requirement necessitates group selectors which have, as far as possible, access to all the switches in each final selector group. The requirements could be met by the use of a uniselector type group selector, which could be stepped in response to the initial digit from the subscriber's dial. Each outlet of the group selector could then be connected to a second uniselector mechanism, which would automatically search for a free final selector in the chosen group. This method would, of course, require 11 uniselectors for each group selector stage. A much better scheme, and the one adopted in

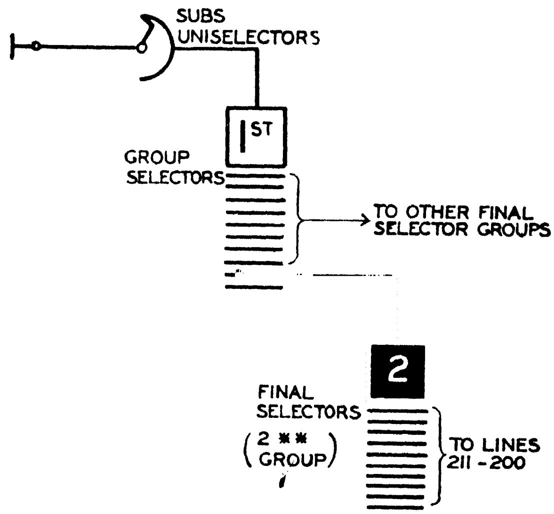


FIG. 22. TRUNKING DIAGRAM OF 1000-LINE EXCHANGE SHOWING INTRODUCTION OF GROUP SELECTORS

practice, is to utilize a 2-motion mechanism for the group selector (Fig. 22). The mechanism is stepped vertically under the control of the initial digit from the subscriber's dial, and then *rotates automatically* over the 10 bank contacts of the selected level to choose a disengaged final selector in the required group. This automatic rotary movement is sometimes known as *non-numerical selection* to distinguish it from the process of numerical selection which is controlled by the dial.

It is important to remember that, whereas the rotary movement of a final selector is controlled by the final digit dialled by the calling subscriber, the rotary motion of each group selector is automatic in operation, and takes place *between* consecutive digits from the calling subscriber's dial. It was seen in Volume I that the construction of the dial makes provision for a minimum period of 200 msec before the impulses of each digit are transmitted. The lost motion period enforced by the mechanical construction of the dial, together with the time taken by the subscriber to pull round the dial to

the finger stop, gives a minimum pause between digits in the order of 400 msec. This period of minimum pause is important, and is primarily provided to allow switches, such as group selectors, to

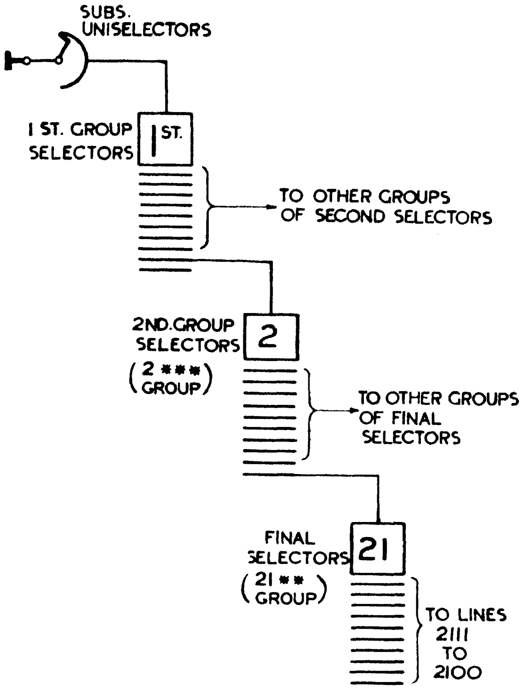


Fig. 23. Trunking Arrangements of 10 000-line Exchange with Subscribers' Uniselectors

hunt over the level to which they are stepped and to seize a selector in the next rank before the following train of impulses is transmitted. Dial tone is returned to the calling subscriber only when a 1st group selector has been seized, but the provision of a period of minimum pause before the transmission of the *first* impulse train tends to reduce premature dialling troubles should the subscriber not listen for dial tone.

10 000-line Exchange. Fig. 23 shows a development of the principle of decimal selection in a 10 000-line exchange utilizing subscribers' uniselectors. When the calling subscriber lifts his receiver the uniselector automatically rotates to seize a free 1st group selector in the common group. The 1st digit steps the group selector to the required level and during the interdigit pause the 1st group selector automatically hunts over the chosen level to seize a free 2nd group selector. The 2nd group selector responds to the 2nd digit and at the end of the 2nd impulse train hunts over the level to find a free final selector. The 3rd digit from the calling subscriber's dial steps the final selector vertically whilst the 4th and last digit directs the rotary motion of the final selector to route the call to the required line.

Fig. 24 shows a comparable trunking diagram for an exchange employing 2-motion linefinders. In this case the lifting of the calling subscriber's receiver energizes the start circuit. A free 1st selector and its associated linefinder are usually pre-selected by the allotter and the start condition causes the linefinder to search for a marking condition on its bank due to the calling line. After seizure of the line, the call is switched to the 1st selector and the call proceeds in exactly the same way as in a uniselector exchange.

Numbering Scheme Restrictions. It has been assumed in the foregoing paragraphs that a 2-digit numbering scheme will provide accommodation for 100 subscribers' lines, a 3-digit scheme for 1000 lines and a 4-digit scheme for 10 000 lines. In practice this theoretical multiple capacity is not obtainable owing to the reservation of certain selector levels.

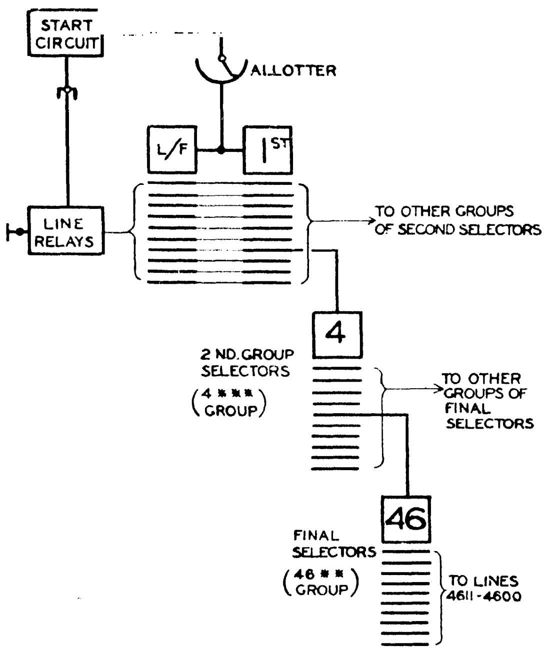


Fig. 24. 10 000-line Exchange with Linefinders

Experience has shown that it is inadvisable to use level 1 of first selectors on account of the danger of mis-routing resulting from false initial impulses. In all automatic systems a false impulse is liable to be transmitted by a subscriber fumbling the cradle switch when removing the receiver. If level 1 were included in the numbering scheme and a

subscriber proceeded to dial a number after inadvertently transmitting a false impulse, a wrong number would be obtained. Moreover, tapping earth or short-circuit faults on subscribers' lines tend to step the first selector to level 1 and the use of this level would therefore incur the risk of false calls during storm conditions. Tests carried out at representative exchanges have shown that some 5 per cent of all calls carried by first selectors are false calls routed to level 1, the percentage being considerably higher on first selectors dealing exclusively with call office traffic. For these reasons it is the normal practice to treat level 1 of the first selector in a switching train as a spare level with its contacts connected to Number Unobtainable Tone.

Level 0 is usually allocated for obtaining access to the operator, whilst level 9 is connected to a special group of second selectors to provide access to various miscellaneous services such as phonograms, inquiries, speaking clock, service P.B.X., test desk, etc. (see Chapter XII). In addition to the reservation of levels 1, 9 and 0, the numbering scheme of any particular exchange may be further restricted by the use of selector levels for outgoing junction routes. As a result of these various restrictions the maximum capacity of a 4-digit exchange is 7000 lines and the capacity is correspondingly smaller if there are outgoing junction routes from selector levels. It should be noted that the above limits do not apply where special "code selectors" are introduced (as in the Director system) in front of the numerical selectors to cater for junction dialling codes. In such circumstances the full 10 levels of the first numerical selectors are available for subscribers' numbers.

Traffic and Trunking. The elementary considerations of this chapter have shown that the economics of an automatic switching system are to a large extent determined by the method of interconnecting the various ranks of switches and on the basis of provision of the switches themselves. Before an automatic exchange can be designed it is necessary, firstly, to know the intensity and nature of the traffic to be carried and, secondly, to determine the most economical arrangement of switching equipment to carry the required traffic. These considerations are examined in some detail in the next chapter.

EXERCISES I

1. Compare the service advantages of automatic and manual switching systems. In what circumstances are the advantages of automatic working most pronounced?

2. Explain why automatic telephony is generally less expensive than a manual switching system in a densely telephoned area.

3. How does the method of switching (i.e. manual or automatic) affect the economics of line plant provision? Illustrate your answer with hypothetical examples.

4. Discuss the problems of providing telephone service in scattered rural areas. How does automatic telephony assist in the solution of these problems?

5. Describe briefly the three main methods of controlling the movements of automatic selectors. Explain concisely what you understand by "step-by-step" selection.

6. Explain, with the aid of a suitable diagram, the various signalling conditions between a subscriber's telephone and the automatic exchange.

7. Describe the general arrangements of a 2-motion selector. How are the bank contacts of such a selector numbered?

8. Explain the need for each of the following tone signals used in automatic exchanges: (*a*) Dialling tone, (*b*) Busy tone, (*c*) Ringing tone. (*C. & G. Telephony, Grade I*, 1941.)

9. Compare the merits of using (*a*) subscribers' uniselectors and, (*b*) linefinders, for connecting subscribers' lines to first selectors. (*C. & G. Telephony, Grade II*, 1944.)

10. Describe the progress of a call through a 4-digit automatic exchange with subscribers' uniselectors and 2-motion selectors. Illustrate your answer with a simple trunking diagram.

CHAPTER II

TRAFFIC AND TRUNKING

The Incidence of Telephone Traffic. Telephone service may be demanded at any hour of the day or night for business, social or any other requirements of the subscriber. The exact time at which any particular call is made depends upon a very wide range of factors which are peculiar to that subscriber alone. The time at which, say, a business subscriber makes a certain call may, for example, depend upon the time at which he arrives at the office, the delivery time of the mail, the volume of other business, and so on. Moreover, calls are originated by subscribers without any knowledge of the demands of other subscribers. It is to be anticipated, therefore, that there will be wide variations in the number of calls originated minute by minute. The factors which influence the incidence of calls are so very diverse that it can be stated with reasonable accuracy that telephone traffic originates in a *pure chance* manner. This statement is not strictly true since the probable number of calls originated at any one time is to some extent dependent upon the number of conversations already in progress. If, for example, 50 subscribers out of a common group of 100 are engaged in conversation, the likelihood of demands for further calls is much less than would be the case if none of the subscribers was already speaking. Under practical conditions the number of subscribers is usually so large in relation to the number of simultaneous conversations that this factor is not of material consequence.

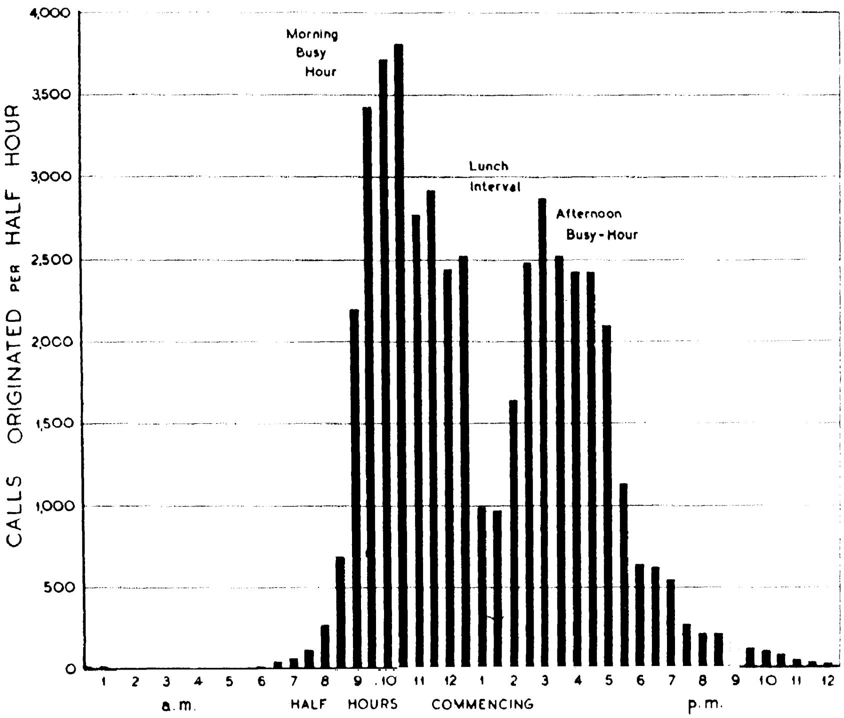


FIG. 25. TYPICAL HOUR-TO-HOUR VARIATIONS IN THE VOLUME OF LOCAL TRAFFIC
(Large commercial city)

In a manual switching system the irregularities in the incidence of calls are to some extent smoothed out by the waiting period before the telephonist answers the call. If, say, 3 or 4 calls originate in rapid succession, a few seconds delay will probably occur before all the connexions are established. A good indication of the adequacy or otherwise of the operating staff can be obtained by observations on the *speed of answer*. In automatic telephony, on the other hand, if a call cannot be completed at the time of its origination, this call is, generally speaking, lost.

In order to assess the quality of service being given to subscribers on an automatic system, it is desirable to know not only the average traffic over a period, but also to be able to estimate as accurately as possible the effect on the service during momentary peak periods of traffic. It is, of course, not possible to foretell the *exact* number of calls which will originate from minute to minute, but use is made of the mathematical theory of probability to determine the *probable* traffic under various conditions.

Hour-to-hour Traffic Variations. Although it is true to say that within a given period of, say, five minutes, telephone calls originate in a pure chance

manner, there are nevertheless certain factors which produce a greater volume of traffic at one time of the day than at other periods. Telephone subscribers in any one area are influenced by certain common habits and customs such as, for example, the adherence to 9.0 a.m. as the starting time of most business offices, more or less common meal times, delivery and dispatch times of mails, unified shop closing times, and so on. These common activities produce well-defined periods of heavy and light traffic which recur at substantially the same time on successive days. It is therefore possible by taking the average traffic over several representative days, to obtain a graph for each exchange showing the distribution of traffic for a 24-hour period.

Fig. 25 shows the hour-to-hour variation of local traffic at an exchange in a typical large commercial city. As is to be expected, the traffic during the night period is negligible. The traffic rises rapidly from 8.30 a.m. onwards and reaches a peak between 10.0 and 10.30 a.m. There is a pronounced drop in traffic during the lunch interval which is followed by a smaller peak of traffic during the afternoon. The distribution and volume of traffic vary somewhat day by day but, apart from special days, such as early closing day, Saturdays, Sundays, and public holidays, the general form of the graph is maintained.

The distribution curves vary considerably for different exchanges. In a residential area, for example, the morning peak of traffic is usually not so well defined and the afternoon and evening traffic is normally greater (in proportion) than in a purely business area. It is interesting to note that in America, where the telephone is used more extensively for social purposes than in this country, the traffic throughout the day is generally more even and in some cases reaches its maximum value in the evening. Some areas such as, for example, ports located in tidal waters, have peaks of traffic which vary day by day in accordance with the times of maximum commercial activity. In such circumstances automatic switching has considerable advantages over manual telephony, owing to the availability of equipment to meet the peak traffic at any time of the night or day.

Not only does the volume of traffic vary hour by hour throughout the day, but the type of traffic also varies. Fig. 26 shows the originated demand trunk traffic during a 24-hour period and should be compared with the local traffic distribution of the same exchange (Fig. 25). It will be noted that the morning peak of trunk traffic occurs somewhat later than the period of maximum local traffic. The ratio

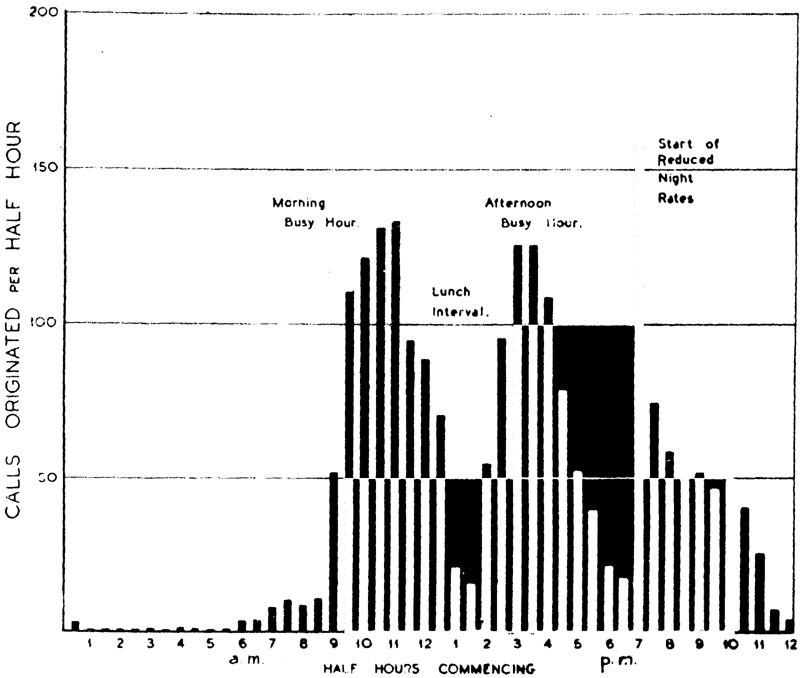


FIG. 26. INCIDENCE OF LONG-DISTANCE TRUNK TRAFFIC AT THE SAME EXCHANGE

of trunk to local traffic during the evening period is also many times greater than the same ratio during the daytime. This is due to the introduction of the cheap night trunk rates which produce a very big demand from 6.30 p.m. onwards. It will also be noted that the peak period of trunk traffic occurs between 7.0 and 7.30 p.m., whereas the peak period of local traffic is between 10.30 and 11.0 a.m.

Different types of call involve the use of different portions of the switching equipment, and it is therefore necessary to know the traffic distribution for each individual class of call in order to provide the correct quantity of switching equipment.

Seasonal Traffic Variations. Mention has already been made of the fact that the volume of traffic at any particular time varies day by day. In some areas there are very large seasonal variations in the

volume of traffic. This is particularly the case at holiday resorts, and at other places where special events are periodically held. Fig. 27 is an interesting example of the variations in the volume of traffic week by week at a typical coastal resort. The average weekly traffic during the winter months is small and represents only about 75 per cent of the average traffic during the summer months. The sudden and pronounced peaks of traffic during the Easter, Whitsun, and August holiday weeks are distinctly shown. In this particular exchange the maximum traffic of the year occurs, rather surprisingly, during the Christmas holiday period. Not only does the *volume* of traffic vary throughout the year but, particularly at seaside resorts, the *type* of traffic (i.e. local or long-distance) also changes very appreciably with the seasons.

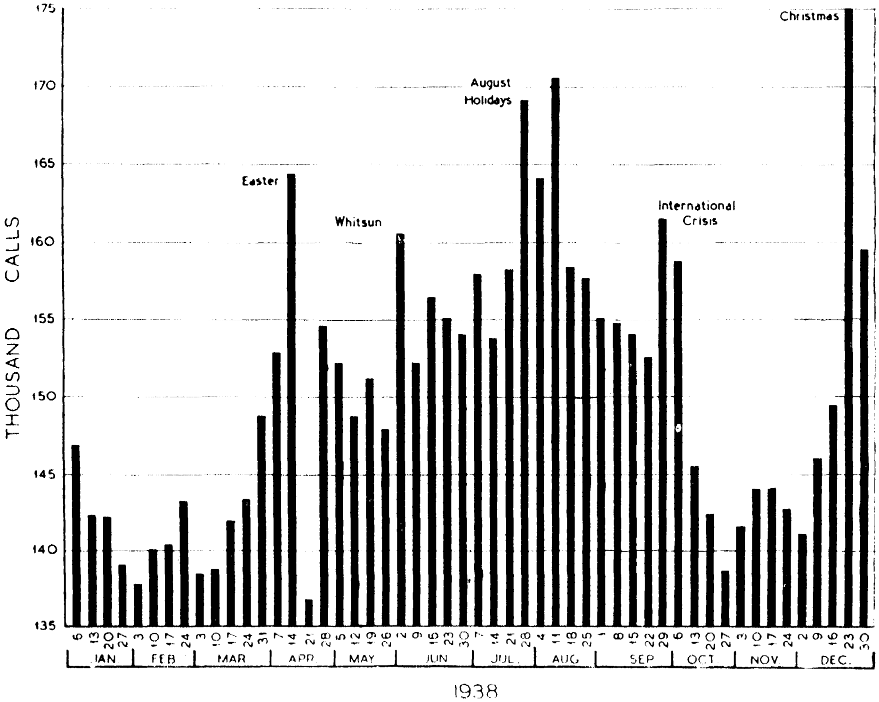


FIG. 27. SEASONAL VARIATIONS IN THE TRAFFIC AT A TYPICAL HOLIDAY RESORT

The Busy Hour. It is a necessary requirement of any telephone switching system that a reasonable standard of service should be available to the subscribers at all times. It follows, therefore, that the quantity of switching equipment (or, in a manual system, the number of operators) should be capable of handling the traffic during the busiest part of the day. For design purposes, one hour of the day is chosen for each exchange which represents the period of greatest traffic. This period is known as the *busy hour* and can occur at any time of the day or night, depending upon the character of the area served. In most areas, the busy hour occurs in the morning between the limits of 9.30 a.m. and 11.30 a.m., and to simplify traffic measurements it is the usual practice in Great Britain to choose the busy hour to correspond with the full and half hours of the clock, e.g. from 9.30 a.m. to 10.30 a.m. or 10.0 a.m. to 11.0 a.m., etc. It has already been seen that the volume of traffic during the busy hour varies from day to day and, to some extent, with the time of the year. For design purposes, the time of the busy hour and the value of traffic during the busy hour are determined from average figures obtained over a period.

It should be clearly understood that the busy hour for local traffic does not necessarily coincide with the busy hour for trunk traffic. Moreover, it is not unusual for "coin-box" and "ordinary" subscribers to produce peaks of traffic at different times.

Day and Busy Hour Calling Rates. For purposes of exchange design, it is usual to express the traffic originated by subscribers in terms of the *busy hour calling rate*. The busy hour calling rate may be defined as the average number of calls originated per subscriber during the busy hour. It may vary from, say, 0·3 for a small rural exchange up to 1·5 for a very busy city area. The calling rates of provincial exchanges range from, roughly, 0·5 to 1·0. Usually, the busy hour calling rates of coin-box, ordinary and P.B.X. subscribers are scheduled separately owing to the special grouping required for such lines.

A further term—*the day calling rate*—is also used to indicate the average number of originated calls per subscriber per day. The day calling rate is of little value for the determination of the quantity of switching equipment, but is necessary

for certain other requirements, such as the estimation of the daily current consumption of the exchange. Normally, the day calling rate is in the order of 6 to 7 times the busy hour calling rate.

Holding Time. As will be seen later it is necessary to know not only the number of calls originated, but also the duration of the calls. The total time for which any circuit (or automatic selector) is held for the purpose of a call is known as the *holding time*. The total holding time of a call is made up partly of the *conversation time* and partly of the *operating time*. From a subscriber's point of view, the conversation time is important whilst in a manual switching system the value of the operating time determines to a large extent the load on the telephonist. In automatic telephony, the *total* holding time is of more importance.

Not only does the conversation time vary with calls of different types, but the time required for setting up and releasing a call is also dependent upon the type of call. It is to be expected, therefore, that the holding times of calls of various types will differ. Moreover, the holding time varies with each individual exchange and it is necessary for design purposes to determine the average holding time of each category of call in a particular exchange.

Measurement of Telephone Traffic. The total cost of providing telephone service can be roughly divided into those charges which are substantially constant and independent of the volume of traffic and those which are to a large extent determined by the amount of traffic. The cost of a subscriber's line and instrument, together with certain essentially individual equipment in the exchange, is totally independent of the number of calls, whereas the quantity of common switching equipment required is almost entirely governed by the volume of traffic.

Under conditions of manual switching, the charges directly attributable to the quantity of traffic are to a large extent determined by the wages and establishment costs of the operating staff. The number of operators required in turn depends primarily upon the number of calls. The work of an operator is mainly concerned with the setting up of a connexion and the subsequent disconnexion of the call. The actual duration of the call does not materially affect the work of the telephonist. It appears, therefore, that from a staffing point of view, the unit of telephone traffic in a manual exchange could be *one call* with perhaps an extra allowance for those calls which require additional operating time.

Apart from the above, the volume of traffic also determines the number of cord circuits required per position and the number of circuits in every junction route. The quantity of such equipment is dependent not only on the *number* of calls, but also upon the *duration* of the calls. For example, 7 cord circuits are sufficient to carry a nominal total of one-hundred-and-forty 3-minute calls in the busy hour but, if the average duration of each call is increased to, say, 6 minutes, a total of 14 cord circuits will be required to carry the same number of calls.

With automatic telephony, a considerably greater proportion of the total annual charges is involved in the common switching equipment. The quantity of this equipment, like the cord circuits of a manual exchange, is dependent upon both the number of calls and the average duration of the calls. Whilst, therefore, telephone traffic may be measured in terms of the number of calls for the purpose of staffing in a manual exchange, a second unit which is a function both of the number of calls and of the duration of the calls is necessary to determine the quantity of switching equipment.

The Unit Call. We have seen that, in a manually operated telephone system, the volume of work presented to the telephonists is primarily dependent upon the number of calls and the type of traffic. For each call the operator must insert a plug into the answering jack, must ascertain the number required and, after testing the required line, must insert the calling plug into the multiple jack of the wanted subscriber. After ringing the required subscriber, the operator is then free to deal with other calls until such time as the first call is finished when the operator is required to meter the call and to take down the connexion.

In order to assess the operating load of a telephonist, calls of all types are compared with a standard *unit call*. The unit call is based on a local call between two subscribers on a large C.B. No. 1 type switchboard and is estimated to require an overall operating time of 18 seconds. The 18 seconds for a unit call is made up of *directly occupied* time, i.e. the time spent by the operator in actually handling the call, and *indirectly occupied* time which is the time spent in performing certain accessory functions not essentially part of the call. The indirectly occupied time provides for the waiting time between calls which is necessary to maintain a satisfactory speed of answer. It also provides a certain amount of flexibility for the handling of fluctuating loads and allows the operator an opportunity to review the conditions on her position. The 18 second unit call does, in fact, consist of 13·2 seconds directly occupied time with the remaining 27 per cent added to cover the indirectly occupied time.

It is clear that the standard load of one telephonist is 200 unit calls per hour. In order to express the work of a telephonist in terms of the unit call, a value has been given to each type of call, and the total load so obtained is known as the *valued load* of the telephonist. In a complex telephone system there are many types of call and, to simplify the process of computing the load of an operator, the values (in terms of the unit call) of the more common types of call are scheduled. Extra allowances can be added where applicable to cater for calls which involve a greater amount of operating time. Table I shows several typical types of call. The list is by no means comprehensive and there are numerous other values to cater for the different methods of operating junction routes, etc. Table II gives a selection of the more common allowances which are added as required to the average values given in Table I.

TABLE I

EQUATED CALL VALUES FOR VARIOUS TYPES OF CALL

Type of Call	Value in Terms of Unit Call
Local call at a manual exchange having a subscribers' multiple of 5000 or more	1·00
Local call at a manual exchange having a subscribers' multiple of less than 2000 working lines	0·90
Local call at an automanual exchange which is connected directly to a line in the service multiple	1·00
Local call at an automanual exchange which is dialled direct to the required subscriber	1·10
Junction or toll call connected over an order-wire circuit	1·35
Junction call over a S.F.J. circuit to a distant manual exchange	1·50
Junction or toll call over a signal circuit direct to a manual exchange	1·90
Junction or toll call over two successive automatic signalling circuits	3·25
Junction or toll call connected over a total of three or more junction links	4·90
Trunk demand call over circuit direct to terminal trunk exchange	10·0
Demand trunk call switched through one intermediate trunk exchange	12·0
Delayed trunk call over circuit direct to terminal trunk exchange	13·0
Delayed trunk call routed via one or more intermediate trunk exchanges	14·5

Apart from the equated call values and the standard additional allowances, cognizance is also taken of a number of factors which tend to reduce the efficiency of a telephonist. Special allowances are, for example, made for a telephonist working on the end position of a suite or at a position adjacent to an angle section where the multiple it not so conveniently placed as on the straight pars of the switchboard. In a similar way allowance is also made when there is an abnormal number of circuits in the outgoing junction multiple or when there is a high percentage of junctions engaged. As there is very little variation in the type of call handled on incoming positions, it is usual to quote the operator's load on such positions in terms of the actual calls handled.

TABLE II

ADDITIONAL ALLOWANCES TO BE ADDED TO AVERAGE EQUATED VALUES WHEN NECESSARY

Item	Additional Value in Terms of Unit Call
Large junction multiple of 1320 jacks and over	0·20
Call passed directly or indirectly over generator signalling circuits	2·20
Call from pre-payment coin-box	1·20
Timed toll call	2·00
For magneto or other exchanges with hand restored indicators	0·17
Dialling 4 digits	0·70
For personal call	15·00
For personal call on demand trunk call	7·00
For transferred charge call	4·50
For checking caller's number (automatic exchanges)	1·50

For the purpose of assessing loads, the traffic on each manual exchange is measured at six-monthly intervals. The traffic record is taken during the two busiest consecutive morning hours on two consecutive and representative days. The required information may be obtained from the call tickets or, especially at the smaller exchanges, a tick record of the calls of various types may be specially arranged.

The Traffic Unit. It has been stated that, to determine the quantity of common switching equipment in an exchange, it is desirable to have a unit of traffic which is a function both of the number of calls and of the average duration of a call. By definition, the intensity of traffic (or the number of *traffic units*) for any specified period is unity when the average number of simultaneous calls during this period is unity. In Great Britain the specified period is the busy hour unless otherwise stated. It follows from the above that a traffic unit is equivalent to the traffic flow in one circuit which is continuously occupied. The number of

traffic units is also numerically equal to the average number of calls which originate during a time equal to the average holding time. It should be clearly understood that the traffic unit (abbreviated T.U.) indicates the *rate* of incidence of traffic during the busy hour, and should not be confused with the "unit call" which of itself is a measure of the total traffic and not the rate of flow of traffic.

If now,

A = total traffic flow (in T.U.s) during the busy hour,

N = number of calls in the busy hour,

T = the average duration of a call expressed as a fraction of 1 hour,

then from the definition,

1 call of 1 hour's duration = 1 traffic unit

N calls each of 1 hour's duration = N traffic units

N calls each of T hours duration = $N \times T$ traffic units

Thus,

$$A = N \times T \text{ traffic units}$$

The traffic flow (T.U.s) for any period can therefore be calculated from the number of calls originated during the period multiplied by the average holding time of a call, the holding time being expressed as a fraction of the period.

Example. At a certain exchange, a total of 5000 calls are originated during the busy hour. If the average holding time of a call is $2\frac{1}{2}$ minutes, calculate the flow of traffic during this period.

Traffic flow (A) = $N \times T$

No. of calls (N) = 5000

Holding time (T) = $2{\cdot}5/60 = 0{\cdot}0416\dot{6}$ hours

Therefore

Traffic flow $= 5000 \times 0{\cdot}0416\dot{6}$
$= 208{\cdot}3$ (T.U.)

There is therefore an average of 208 simultaneous conversations throughout the busy hour.

Grade of Service. In any exchange system the theoretical maximum traffic would occur if one-half of the total subscribers were engaged in conversation with the remaining one-half of the subscribers. Such conditions are never encountered in practice, and it is unnecessary to provide anything like this quantity of switching equipment. The *average* rate of traffic flow during the busiest hour of the exchange can be readily ascertained from observations of the number of calls and of the average holding time of these calls. From this information (and by making certain justifiable assumptions) it is possible to determine the *mathematical probability* of the number of simultaneous

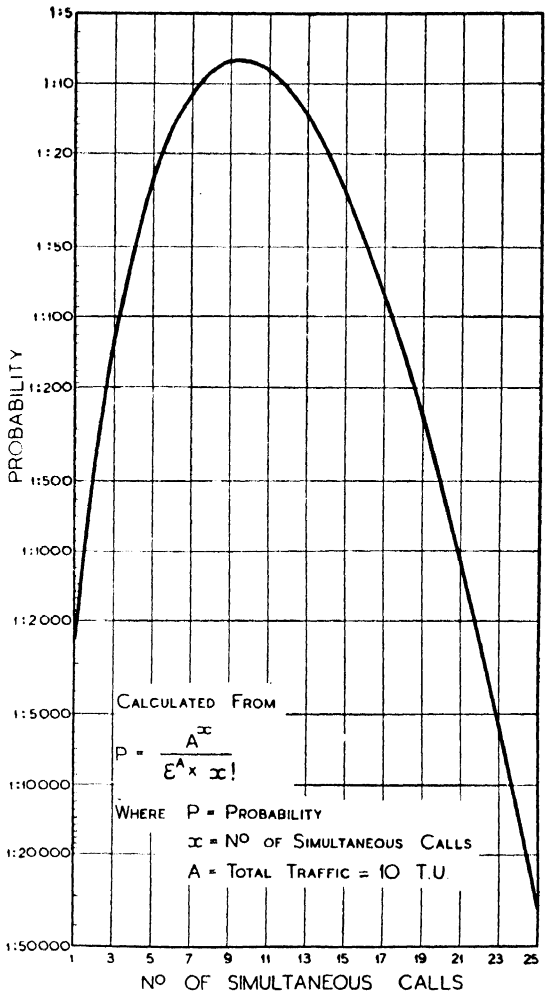


Fig. 28. Mathematical Probability of There Being 1, 2, 3, etc., Simultaneous Calls at a Typical 500-line Exchange

calls at any particular instant. Fig. 28 illustrates the result of such a calculation. The curve is calculated for a 500-line exchange with a busy hour calling rate of 0·6, and an average holding time of 2 minutes, i.e. the traffic flow during the busy hour is 10 T.U. The probability of there being exactly 10 simultaneous conversations is 1 in 8 approximately, but the probability of there being exactly 20 simultaneous conversations is only 1 in 500. The probability of there being a greater number of

calls decreases rapidly and there is only 1 chance in 34 000 of there being 25 simultaneous calls. The mathematical probability of there being 30 calls is well over 1 in 5 million!

It is clear from the above that it is unnecessary (and certainly uneconomical) to provide switching plant to cater for the very occasional chance that the equipment may be required. In all automatic exchange design work, it is necessary to strike a compromise between the cost of the equipment and the standard of service given to the subscriber.

The proportion of calls which are allowed to fail during the busy hour owing to the limitation of the amount of switching plant is known as the *Grade of Service*. In a normal 4-digit exchange employing subscribers' uniselectors (Fig. 23) a call can fail due to insufficiency of plant at any of the following stages:

(*a*) The uniselector may fail to find an outlet to a free 1st selector.

(*b*) The 1st selector may fail to find an outlet to a free 2nd selector on the selected level.

(*c*) The 2nd selector may fail to find a free outlet to the required group of final selectors.

If a 1st or 2nd selector fails to find an outlet, the wipers step to the 11th rotary position and busy tone is returned to the subscriber, but with subscribers' uniselectors, the hunting is continued until either a free outlet is found or the subscriber abandons the call. For the sake of uniformity, it is assumed that the call is lost if a uniselector fails to find a free 1st selector during its first complete search of the outlets. It has been found that, under normal working conditions, this assumption introduces only a slight error which can be neglected. For all practical purposes there are three points at which a call may be lost in a 4-digit exchange due to insufficiency of plant.

Whilst it is the *overall* grade of service which determines the efficiency of a system, the grade of service at each switching stage must be considered separately in order to calculate the number of switches required to carry the traffic at that stage. There are, moreover, certain practical difficulties in providing design tables to meet a specified overall grade of service on account of the large number of different arrangements of switching stages. It is the practice in the Post Office to specify a grade of service of 1 lost call in 500 per switching stage. The standard grade of service is usually expressed as "a grade of service of 0·002" or "1 in 500." If 1 call out of every 500 is lost at each switching stage, it is clear that (in a 4-digit exchange) approximately 3 calls are lost for each 500 originated, and hence the overall grade of service is roughly 3 in 500, or 0·006. This method of determining the overall grade of service is not strictly accurate, since it ignores the reduction in traffic stage by stage due to lost calls. With a good grade of service and a reasonably small number of stages, however, the error is not appreciable.

The greatest difficulty in calculating the overall grade of service lies in the fact that all the traffic switched at the first stage does not necessarily proceed to the remaining stages. (Some calls are routed to the manual board or to other exchanges from the levels of 1st or 2nd selectors.) The peaks of traffic with different types of call may occur at different times, and it is this non-coincidence of the traffic peak at the various stages which makes a reliable figure for the overall grade of service difficult to determine. In actual practice, it is impossible to maintain an exact grade of service of 1 in 500 per stage, owing to fluctuations in traffic day by day. To avoid frequent changes of the quantity of switching equipment, an exchange is designed to have a grade of service of 1 in 1000 (per switching point), and additional equipment is provided only when the grade of service falls below 1 in 200.

Full Availability. It has been seen in Chapter I that in the Strowger system of automatic telephony a subscriber's uniselector searches for and seizes a free 1st selector when the calling subscriber's receiver is lifted. In a similar manner, when a group selector is stepped to the desired level, rotary hunting takes place over that level in a search for a free selector of the next stage. If the total number of selectors at any one stage is not greater than the number of bank contacts of the preceding stage, then it is clear that the calling subscriber (or group selector) has access to *all* switches of the next rank. This condition is known as *full availability*.

A simple example of full availability conditions between the banks of subscribers' uniselectors and the associated 1st selectors is illustrated in Fig. 29. In this example, it is assumed that there are 20 subscribers' uniselectors on each shelf of the uniselector rack. The uniselectors each have 10 outlets and the banks of the uniselectors on each shelf are multipled together contact to contact. Five such shelves are commoned together and the 10 common outlets from all the uniselectors are routed to 10 1st selectors. With this scheme any one subscriber has access to any one of the available 1st selectors in the exchange. The connecting links or circuits between successive stages of selectors are commonly known as *trunks* and in Fig. 29 there are 10 trunks from the subscribers' uniselector banks to 1st selectors.

The same conditions apply at each switching

stage. If, for example, there are 10 contacts on each level of the 1st selectors, and the traffic is such that 10 or less 2nd selectors are required from each level, then full availability conditions exist between the 1st and 2nd selectors.

The method of connecting the outlets of one selector to the selectors of the next stage is known generally as *interconnecting*. Full availability conditions present the most straightforward case of interconnecting and it is desirable to examine the behaviour of full availability groups of circuits before proceeding to the more complicated systems of interconnexion.

Traffic Capacity of a Full Availability Group. One of the first requirements in the design of an automatic exchange is to know the number of trunks required to carry a given volume of traffic with a specified grade of service. The number of trunks, in turn, determines the number of selectors required in the next stage. Mathematical solutions to the problem of the number of switches required to carry a given amount of traffic have been developed by Erlang, Grinsted, Lely, Molina, Lubberger, and many others. Although the formulae derived vary from one another due to differing assumptions made, the differences are, generally speaking, small when applied to actual working conditions.

The assumptions and solution evolved by Erlang are considered to be those most nearly suited to the conditions encountered in practice with the standard switching system of the Post Office. Erlang's formula for a full availability group gives the relation between the proportion of lost calls, the number of outlets tested and the average volume of traffic.

Thus,

$$B = \frac{\dfrac{A^N}{N!}}{1 + A + \dfrac{A^2}{2!} + \dfrac{A^3}{3!} + \dfrac{A^4}{4!} + \ldots \text{ to } \dfrac{A^N}{N!}} \quad . \quad (1)$$

where

B = proportion of lost calls (i.e. the grade of service),

A = average traffic offered (T.U.),

N = number of circuits (or trunks),

$2!$ = factorial 2 = 2×1,

$3!$ = factorial 3 = $3 \times 2 \times 1$,

$N!$ = factorial $N = N \times (N-1) \times (N-2) \ldots \times 3 \times 2 \times 1$.

Erlang's formula is based on a series of assumptions and is applicable therefore only when the conditions approximate to the theoretical assumptions of the equation. The assumptions underlying the derivation of the formula are:

1. That the traffic is pure chance traffic, i.e. that the calls occur individually and collectively at

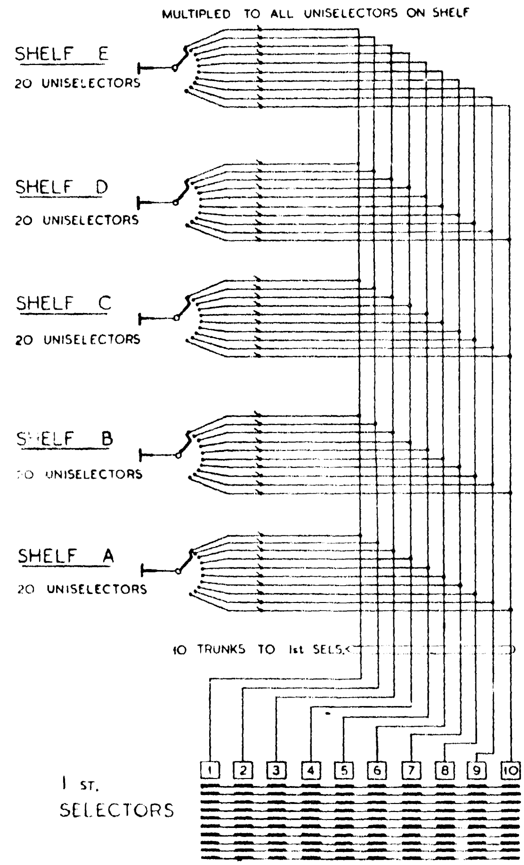


FIG. 29. FULL AVAILABILITY CONDITIONS BETWEEN SUBSCRIBERS' UNISELECTORS AND 1ST SELECTORS

random. For such conditions to exist an infinite number of subscribers or other sources of traffic is required, but in practice the error is small if the number of sources exceeds, say, 100.

2. That full availability conditions exist, i.e. that each switch can test every available trunk to a finite number of selectors in the next stage.

3. That the traffic is the average traffic of a large number of busy hours. (It has been seen that the amount of traffic varies considerably from busy hour to busy hour and the formula assumes the

value of traffic obtained from averaging a large number of busy hours.)

4. That calls which originate when all trunks are busy are lost, and that all such lost calls have a zero holding time.

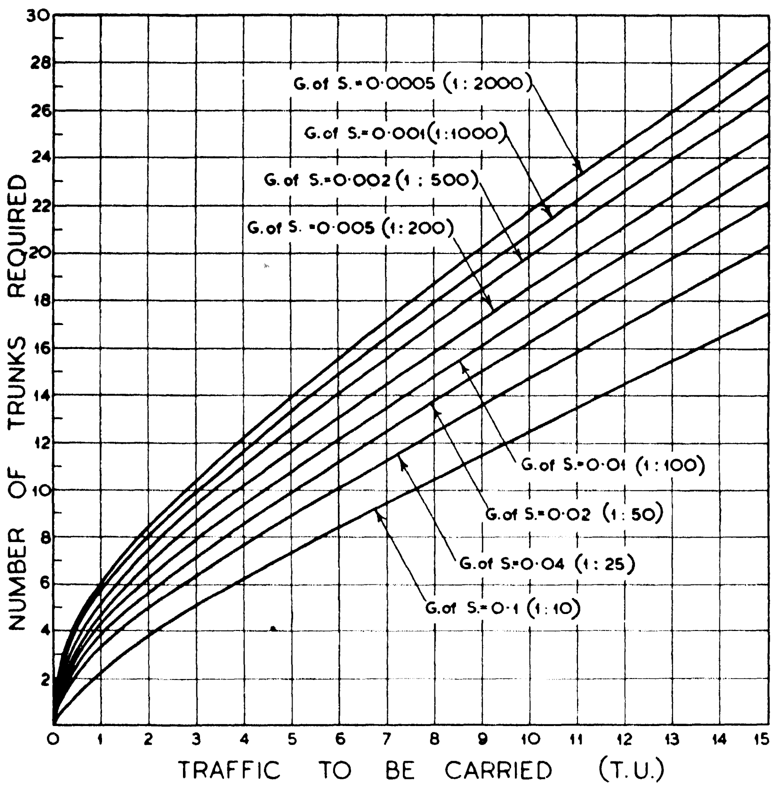


FIG. 30. RELATIONSHIP BETWEEN NUMBER OF TRUNKS REQUIRED AND VOLUME OF TRAFFIC FOR VARIOUS GRADES OF SERVICE (FULL AVAILABILITY CONDITIONS)

5. That statistical equilibrium conditions exist. Statistical equilibrium implies that the number of calls which originate in a very short element of time are equal on an average to the number of calls which terminate during the same time, i.e. that there is no tendency for the traffic as a whole to rise or fall.

The calculation of the traffic capacity of a full availability group by means of Erlang's formula becomes somewhat laborious when a number of results are required. Tables have therefore been prepared to show, for various grades of service, the number of trunks required in a full availability group when the total traffic is known. Typical values of the traffic capacity of groups up to 100 trunks are given in Table III of Appendix I. Fig. 30 shows the relationship in graphical form. It will be noted that for small groups of trunks the traffic capacity is low but as the number of trunks increases beyond, say, 10, the curves become more and more linear.

It will be noted that the denominator of Erlang's formula is part of the exponential series:

$$\varepsilon^A = 1 + A + \frac{A^2}{2!} + \frac{A^3}{3!} \cdot \cdot \cdot \quad \cdot \cdot \cdot + \text{etc., to infinity}$$

If the number of trunks (N) in Equation (1) is infinitely large, then:

$$B = \frac{\frac{A^N}{N!}}{\varepsilon^A} = \frac{A^N}{\varepsilon^A \times N!} \quad . \quad (2)$$

This is the expression obtained by Poisson and, although it is based on the assumption that there are an infinite number of trunks, it can be used without material error for calculating the traffic capacity of large full availability groups where N is relatively large and the grade of service is good.

Probability of "x" Simultaneous Calls. Erlang's equation can be used to calculate the probability of there being exactly "x" simultaneous calls. If the *average* number of simultaneous calls is A and the total number of trunks is N, the probability of exactly x trunks being engaged is:

$$\frac{\frac{A^x}{x!}}{1 + A + \frac{A^2}{2!} + \frac{A^3}{3!} + \cdot \cdot \cdot + \frac{A^N}{N!}} \quad . \quad (3)$$

It follows that the probability of all (N) trunks being simultaneously engaged is:

$$\frac{\frac{A^N}{N!}}{1 + A + \frac{A^2}{2!} + \frac{A^3}{3!} + \cdot \cdot \cdot + \frac{A^N}{N!}} \quad . \quad (4)$$

When N is infinitely large Equation (3) reduces to:

$$\frac{A^x}{\varepsilon^A \times x!} \text{ (Grinsted's formula)} \quad . \quad (5)$$

Traffic Offered to Each Trunk in a Full Availability Group. Erlang's formula may be used to determine the traffic offered to each contact in any full availability group. By definition, the grade of service is the ratio of traffic lost to the total originated traffic, i.e.

$$B = \frac{a}{A} \quad . \quad . \quad . \quad (6)$$

where B = grade of service,
a = traffic lost,
A = total traffic offered.

Substituting in Erlang's formula (Equation (1)):

Lost traffic

$$a = A \times \frac{\dfrac{A^N}{N!}}{1 + A + \dfrac{A^2}{2!} + \dfrac{A^3}{3!} + \ldots + \dfrac{A^N}{N!}} \quad (7)$$

The traffic offered to 1st trunk
= A (total traffic)

The traffic offered to 2nd trunk
= the traffic lost from 1st trunk

$$= A \times \frac{\dfrac{A}{1}}{1 + A} \text{ (Equation 7)}$$

$$= \frac{A^2}{1 + A} \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Similarly,

the traffic offered to 3rd trunk
= the traffic lost from 2nd trunk

$$= A \times \frac{\dfrac{A^2}{2 \times 1}}{1 + A + \dfrac{A^2}{2 \times 1}}$$

$$= \frac{A^3}{2\left(1 + A + \dfrac{A^2}{2}\right)} \quad . \quad . \quad . \quad . \quad (9)$$

And,

the traffic offered to 4th trunk
= the traffic lost from 3rd trunk

$$= A \times \frac{\dfrac{A^3}{3 \times 2 \times 1}}{1 + A + \dfrac{A^2}{2 \times 1} + \dfrac{A^3}{3 \times 2 \times 1}}$$

$$= \frac{A^4}{6\left(1 + A + \dfrac{A^2}{2} + \dfrac{A^3}{6}\right)} \quad . \quad . \quad (10)$$

Whilst,

the traffic offered to Nth trunk
= the traffic lost from $(N - 1)$ trunk

$$= A \times \frac{\dfrac{A^{(N-1)}}{(N-1)!}}{1 + A + \dfrac{A^2}{2!} + \dfrac{A^3}{3!} + \ldots + \dfrac{A^{(N-1)}}{(N-1)!}} \quad . \quad (11)$$

By this means, it is possible to calculate the traffic offered to any trunk in a full availability group. It should be noted that if there are N trunks in a group then the traffic offered to the $(N + 1)$th trunk is the lost traffic. If this value is divided by the originated traffic offered to the 1st trunk, then the grade of service is obtained.

As before, the process of evaluating the traffic offered to each contact in a full availability group by the application of Erlang's formula is somewhat laborious, especially when different values of originated traffic are to be considered. Table I of Appendix I has been prepared on the above basis and shows (to 5 decimal places) the traffic offered to each contact in a full availability group for various values of originated traffic.

It is sometimes necessary to determine the traffic offered to the individual trunks of a full availability group for intermediate values of originated traffic. Figs. 31 and 32 show graphically the traffic offered to each contact for various values of total traffic. By the use of these curves it is readily possible to read off the traffic offered to any particular contact for any value of total traffic. If, for example, the total traffic offered to a full availability group is 2·4 T.U., the traffic offered to the 8th trunk is 0·02 T.U. Similarly, if a full availability group of 10 trunks is offered 3 T.U., then the amount of traffic lost (i.e. the traffic offered to the 11th trunk) is 0·0023 T.U., which gives a grade of service of 0·0023/3 or 0·00077 approx.

Traffic Carried by Each Trunk in a Full Availability Group. The traffic carried by the 1st trunk of a full availability group can be readily calculated by a direct application of Erlang's formula, thus:

Traffic offered to 1st trunk

$$= A$$

Traffic lost from 1st trunk

$$= \frac{A^2}{1 + A} \text{ (Equation 8)}$$

∴ Traffic carried by 1st trunk

$$= A - \frac{A^2}{1 + A}$$

$$= \frac{A}{1 + A} \quad . \quad . \quad . \quad (12)$$

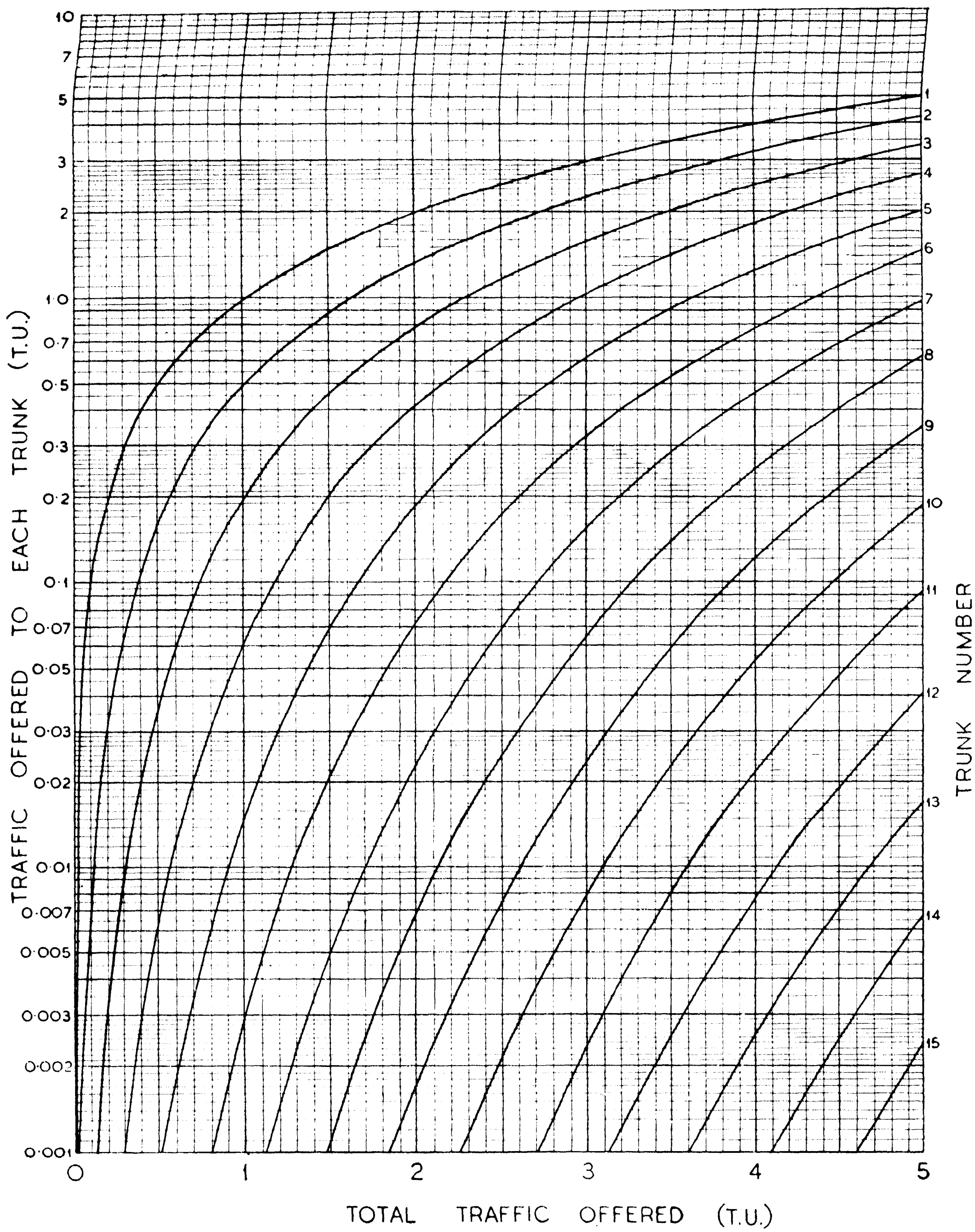


Fig. 31. Traffic Offered to Each Trunk in a Full Availability Group
(Total traffic from 0–5 T.U.)

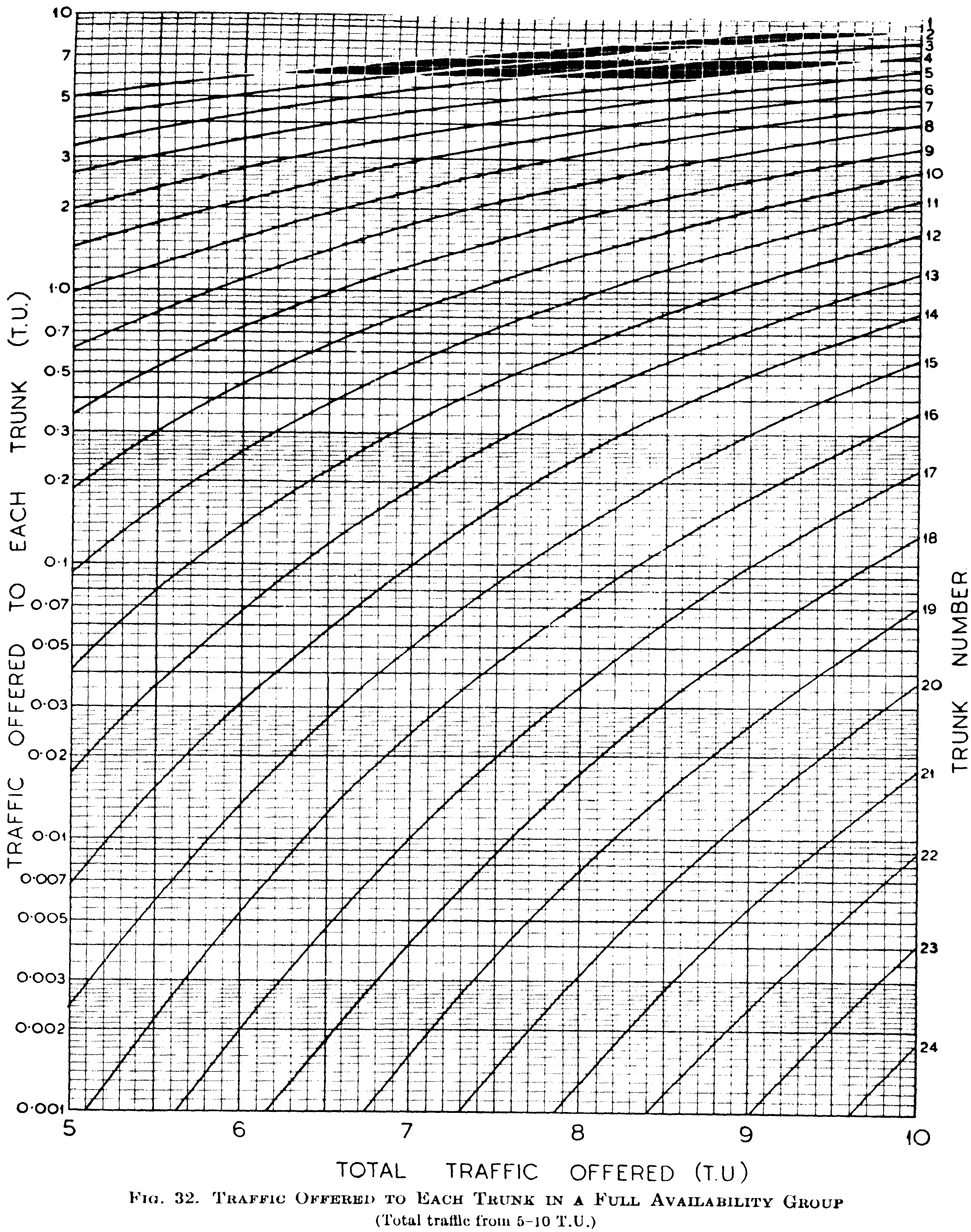


FIG. 32. TRAFFIC OFFERED TO EACH TRUNK IN A FULL AVAILABILITY GROUP
(Total traffic from 5–10 T.U.)

This method of subtracting the traffic passed on from the traffic offered to a trunk in order to determine the traffic carried by the trunk can be applied to any trunk of a full availability group. To illustrate, the traffic carried by the 6th trunk of a group may be obtained by subtracting the traffic offered to the 7th trunk of the group from the traffic offered to the 6th trunk. From the curves of Fig. 31, when the total traffic is 3 T.U., the traffic offered to the 7th trunk is 0·154, whilst the traffic offered to the 6th trunk is 0·32 T.U. Hence, the traffic carried by the 6th trunk of the group (when the originated traffic is 3 T.U.) is 0·32 − 0·154 = 0·166 T.U. For convenience of reference the traffic carried by each trunk of a full availability group for a limited range of total traffic is tabulated in Appendix I (Table II).

EXAMPLE. A full availability group of 10 trunks is offered a total traffic of 4 T.U. Calculate the traffic carried by each of the first three trunks and the grade of service given by the full 10 trunks.

Traffic passed on from 1st trunk

$$= \frac{4^2}{1+4} \text{ (Equation 8)}$$
$$= 3{\cdot}2 \text{ T.U.}$$

Similarly, traffic passed on from 2nd trunk

$$= \frac{4^3}{2\left(1+4+\frac{4^2}{2}\right)} \text{ (Equation 9)}$$
$$= 2{\cdot}461 \text{ T.U.}$$

And traffic passed on from 3rd trunk

$$= \frac{4^4}{6\left(1+4+\frac{4^2}{2}+\frac{4^3}{6}\right)} \text{ (Equation 10)}$$
$$= 1{\cdot}803 \text{ T.U.}$$

Thus traffic carried by 1st trunk

$$= 4 - 3{\cdot}2 \text{ T.U.}$$
$$= \underline{0{\cdot}8 \text{ T.U.}}$$

Traffic carried by 2nd trunk

$$= 3{\cdot}2 - 2{\cdot}461 \text{ T.U.}$$
$$= \underline{0{\cdot}739 \text{ T.U.}}$$

Similarly,

traffic carried by 3rd trunk

$$= 2{\cdot}461 - 1{\cdot}803$$
$$= \underline{0{\cdot}658 \text{ T.U.}}$$

From Equation (1),

grade of service

$$B = \frac{\frac{4^{10}}{10!}}{1+4+\frac{4^2}{2!}+\frac{4^3}{3!}+\ldots+\frac{4^{10}}{10!}}$$
$$= \underline{0{\cdot}005 \text{ approx.}}$$

Last Contact Traffic. If the traffic carried by the last trunk is known, it is possible to calculate the grade of service for a given volume of total originated traffic. Conversely, the total traffic offered to the group can be found if the last contact traffic and the lost traffic are known. Assume that the last contact is the Nth trunk.

Then from Erlang's Equation (1),

proportion of lost calls

$$B = \frac{\frac{A^N}{N!}}{1+A+\frac{A^2}{2!}+\ldots \text{ to } \frac{A^{(N-1)}}{(N-1)!}+\frac{A^N}{N!}} \text{ (Equation 1)}$$

If B_1 is the proportion of calls passed to the Nth trunk (i.e. lost from the $(N-1)$th trunk)

$$B_1 = \frac{\frac{A^{(N-1)}}{(N-1)!}}{1+A+\frac{A^2}{2!}+\ldots \text{ to } \frac{A^{(N-1)}}{(N-1)!}} \quad . \quad . \quad (13)$$

Transposing Equation (1),

$$B\left(1+A+\frac{A^2}{2!}+\ldots \text{ to } \frac{A^{(N-1)}}{(N-1)!}+\frac{A^N}{N!}\right) = \frac{A^N}{N!}$$

or

$$B\left(1+A+\frac{A^2}{2!}+\ldots \text{ to } \frac{A^{(N-1)}}{(N-1)!}\right) = \frac{A^N}{N!} - \frac{BA^N}{N!}$$
$$= \frac{A^N(1-B)}{N!} \quad . \quad . \quad . \quad (14)$$

Transposing Equation (13),

$$B_1\left(1+A+\frac{A^2}{2!}+\ldots \text{ to } \frac{A^{(N-1)}}{(N-1)!}\right) = \frac{A^{(N-1)}}{(N-1)!} \quad . \quad (15)$$

Dividing (15) by (14),

$$\frac{B_1}{B} = \frac{A^{(N-1)}}{(N-1)!} \times \frac{N!}{A^N(1-B)} = \frac{N}{A(1-B)}$$

from which

$$B_1 = \frac{BN}{A(1-B)} \quad . \quad . \quad . \quad . \quad (16)$$

Now, the last trunk traffic

$$= AB_1 - AB$$

$$= \frac{BN}{(1-B)} - AB$$

$$= B\left(\frac{N}{1-B} - A\right) \quad . \quad (17)$$

If the grade of service is reasonably good, $(1-B)$ is nearly equal to 1. Under these conditions,

last trunk traffic

$$= B(N-A) \text{ approx.} \quad . \quad (18)$$

This approximation is quite satisfactory for most calculations but may lead to excessive errors if there is a very large number of trunks.

EXAMPLE. Records of the traffic on a full availability group of 20 trunks show that the last contact traffic is 0·01 T.U. and the traffic lost due to all trunks being engaged is 0·02 T.U. Calculate the total traffic offered to the group and the grade of service.

From Equation (17),
last trunk traffic

$$= B\left(\frac{N}{1-B} - A\right)$$

If $N = 20$

and $B = a/A = 0{\cdot}02/A$,

then
$$0{\cdot}01 = \frac{0{\cdot}02}{A}\left(\frac{20}{1 - \frac{0{\cdot}02}{A}} - A\right)$$

from which $A = \underline{\underline{13{\cdot}34 \text{ T.U.}}}$

and $B = 0{\cdot}02/A = \underline{\underline{0{\cdot}001499}}$

If the approximate formula (Equation (18)) is used:

$$0{\cdot}01 = \frac{0{\cdot}02}{A}\left(20 - A\right)$$

or $A = \underline{\underline{13{\cdot}3\dot{3} \text{ T.U.}}}$

and $B = \underline{\underline{0{\cdot}0015}}$

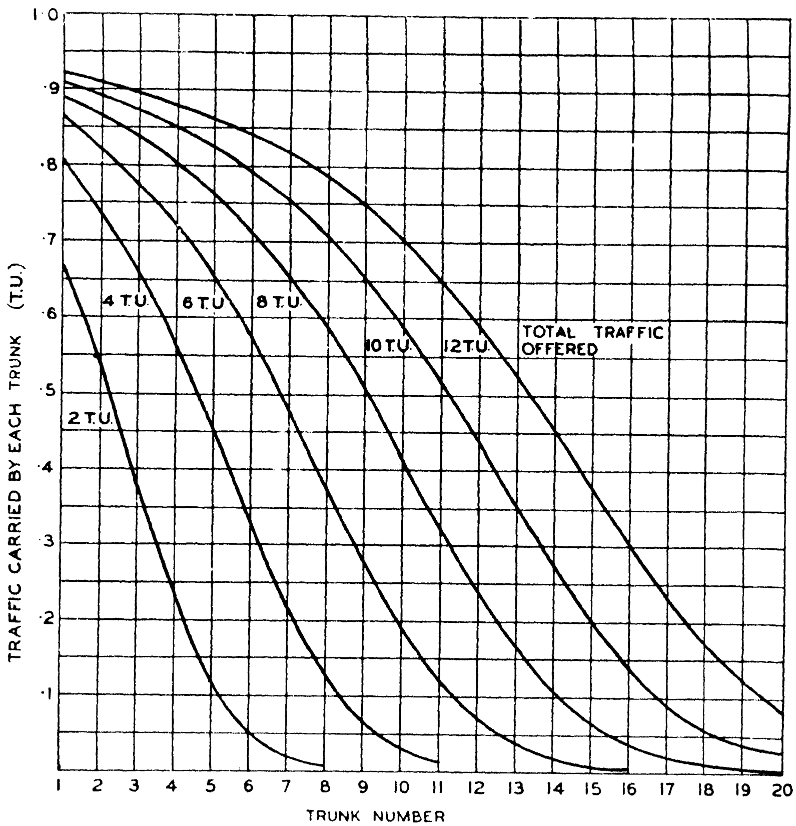


FIG. 33. DISTRIBUTION OF TRAFFIC OVER THE OUTLETS OF A GROUP (FULL AVAILABILITY CONDITIONS)

Distribution of Traffic Over the Outlets of a Group. It has been shown how, by means of Erlang's theorem, it is possible to calculate the traffic carried by each outlet in a full availability group. An examination of Fig. 33 shows that the early choices of a group carry the bulk of the traffic, whilst the later choices carry only a very small proportion of the total traffic. When, for example, the applied traffic is 8 T.U., the first 9 contacts each carry more than 0·5 T.U. and between them absorb over 6·6 T.U. out of the original total of 8 T.U. Contacts 10 to 18 are required to carry the residue of some 1·4 T.U., which gives an average

traffic loading of approximately 0·16 T.U. for the later choices. The later choices are, of course, necessary to provide the required grade of service, but to provide for this the later choices (especially the last two or three) are very wastefully employed.

In some of the earlier systems of automatic telephony an arrangement, known as a *slipped*

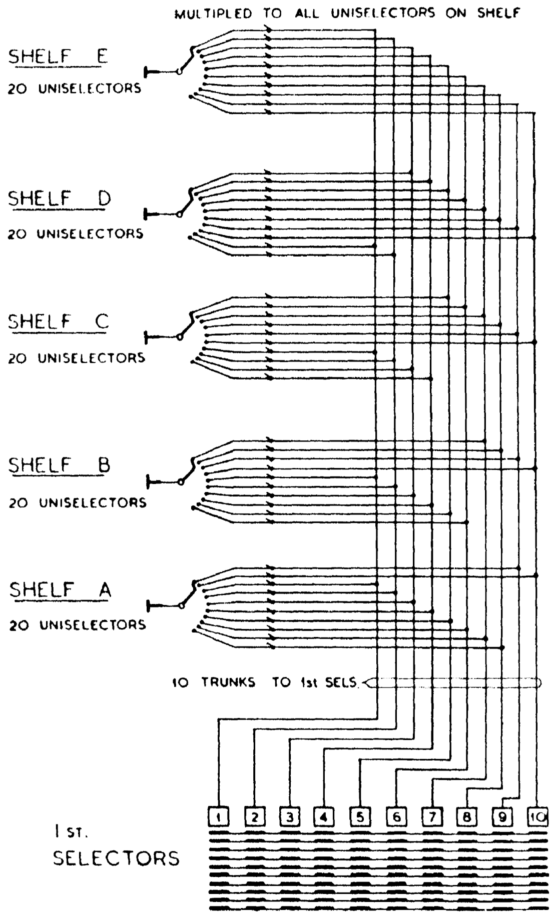


Fig. 34. Principle of the Slipped Multiple

multiple, was sometimes used to increase the traffic capacity of the later choices. The principle of the slipped multiple is illustrated in Fig. 34. The arrangement is fundamentally similar to the full availability conditions already considered in Fig. 29, but the multiple is arranged so that each subscriber's uniselector or group of uniselectors tests the trunks in a different order. The uniselectors on shelf E have their first trunk connected to selector No. 1, whilst uniselector shelves D, C, B, and A, are arranged so that their first choices are selectors 3, 5, 7, and 9 respectively. By this means, the traffic offered to each selector is roughly the same and all switches carry equal volumes of traffic (i.e. about 0·34 T.U.). The use of a slipped multiple levels out the traffic carried by each switch in the group and therefore equalizes the amount of wear. The slipped multiple principle is also of value in reducing the average number of steps taken to find a free trunk to a selector of the next stage. This in turn minimizes wear and reduces the hunting time. In addition, the use of a slipped multiple does to some degree restrict the extent of a service failure should an early choice trunk become faulty. If in Fig. 29 selector No. 1 is faulty then the service to all subscribers is affected, whereas with the slipped multiple scheme (Fig. 34) selector No. 1 is the first choice for only a limited number of uniselectors. Apart from these advantages, however, the slipped multiple *does not in any way increase the total traffic capacity* of the group of selectors. The traffic carried by the arrangement shown in Fig. 34 is exactly the same as the straightforward multiple arrangement of Fig. 29. Moreover, the stepping or slipping of the multiple connexions between uniselectors very considerably adds to the difficulties of tracing connexions. The slipped multiple is now very little used except in a few special circumstances.

The Optimum Size of a Full Availability Group. It will be noted from Fig. 33 that the traffic carried per outlet of a full availability group increases with the value of the total traffic offered to the group. When, for example, the total traffic is 2 T.U. the traffic carried by the first outlet is 0·67 T.U., whilst, when the originating traffic is 10 T.U., the traffic carried by the first outlet is 0·91 T.U. It appears, therefore, that the selectors of a large group are more efficiently loaded than the selectors in a smaller group of trunks. Each value of total originated traffic requires a critical number of trunks to provide a specified grade of service. If the total traffic is divided by the number of trunks required, the result is the average traffic per trunk. Fig. 35 shows the average traffic per trunk for various values of originated traffic. It will be seen that the average loading increases rapidly at first, but later flattens out to give less gain of efficiency when the total traffic values are greater than, say, 10 T.U.

The effect on the grade of service of a temporary overload must also be considered. It has already been stated that, when the total traffic is large, the traffic carried by the first choice is upwards of 0·9 T.U., whereas for small values of total traffic the traffic carried by the first choice is considerably lower. It is to be expected, therefore, that since the early choice trunks of a large group are more

efficiently loaded they are less likely to withstand a temporary overload than the similar outlets of a smaller group. In Fig. 36 the effect of overload on the grade of service is shown for groups of various sizes. In each case sufficient trunks are provided to give a normal grade of service of 0·002. It will be seen from these curves that with a group of 10 trunks a 15 per cent increase in traffic causes the grade of service to drop to about 0·005. With a group of 40 trunks, however, the grade of service falls to roughly 0·0123 with the same percentage overload. It is important, therefore, that in the design of large full availability groups, due allowance be made for the effect of overload.

It is the practice in the Post Office to guard against appreciable decrease in the grade of service by specifying that the nominal grade of service should be 0·002 but that this grade of service shall not deteriorate beyond 0·01 if the traffic increases by 10 per cent. It is clear from Fig. 36 that the latter requirement is the determining factor only when the number of trunks exceeds about 70.

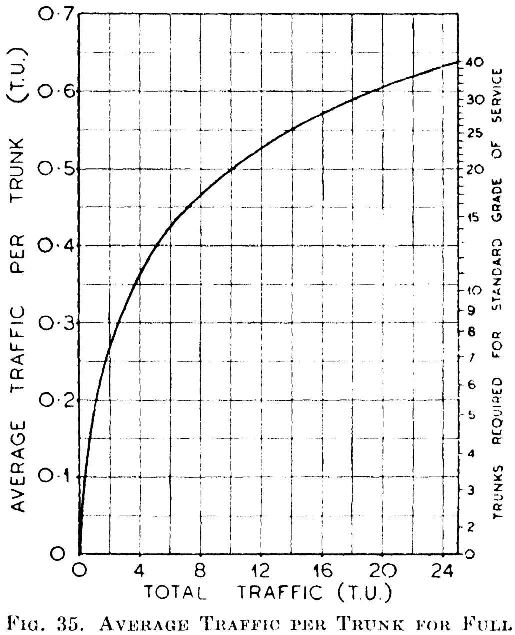


FIG. 35. AVERAGE TRAFFIC PER TRUNK FOR FULL AVAILABILITY GROUPS OF VARIOUS SIZES

(Groups designed to give same grade of service)

In any specific circumstances there is an optimum size of group which gives the most economical arrangement. An increase in the number of trunks to provide a larger group results in a higher average value of traffic carried by each trunk, and consequently reduces the number of selectors required in the next stage. It has been seen that this gain is appreciable as the number of trunks is increased up to 15 or 20, but beyond this there is very little advantage in the adoption of larger groups. The economic advantage of large groups must be

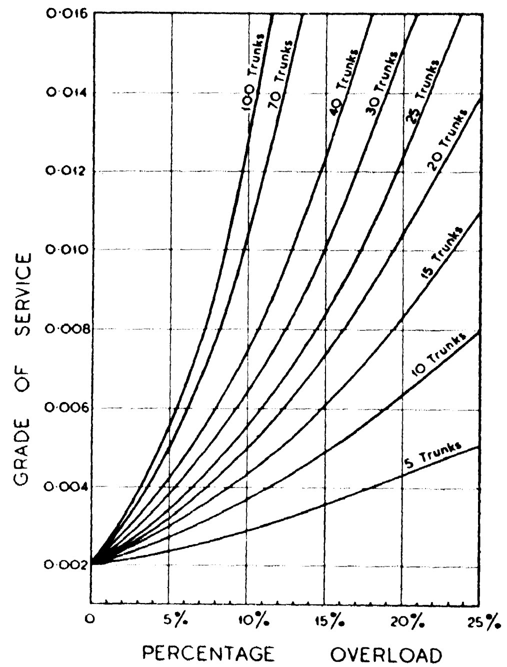


FIG. 36. EFFECT OF OVERLOAD ON GRADE OF SERVICE

weighed against the resultant increased cost of providing switches with a greater number of contacts. The problem involves not only a knowledge of the total traffic to be carried but also of the number of sources from which this traffic originates, and can only be solved by an analysis of the particular conditions obtaining. In practice the question is much simplified by the adoption of standard switch mechanisms with a fixed bank contact capacity.

Effect of Number of Trunks on the Grade of Service. It is interesting to examine how the grade of service improves as the number of trunks is increased. Fig. 37 shows the grade of service for various numbers of outlets. When the total traffic is 6 T.U., 14 trunks are required to provide the standard grade of service of 0·002. An increase of 1 additional trunk improves the grade of service to approximately 0·001, whereas, on the other hand, a reduction of 1 trunk worsens the grade of service to about 0·005. The effect is even more marked for smaller values of traffic but, when the total traffic is large (e.g. 18 T.U.), a change of 1 in the number of trunks produces a much smaller change in the grade of service. It is clear from these curves

that, although the early choice switches carry the bulk of the traffic, it is the little used late choices which determine the grade of service. The curves show the importance of avoiding, wherever possible, the withdrawal of a switch from service. With a total traffic of 2 T.U. and 7 trunks, for example, the grade of service is approximately

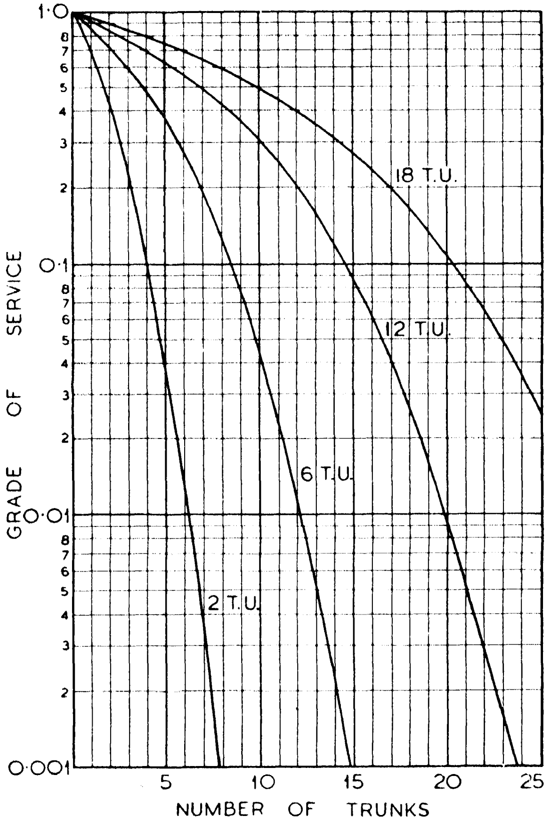


Fig. 37. Variation of Grade of Service with Number of Trunks

0·0034, but if one of the 7 trunks is ineffective due to a faulty selector, the grade of service falls to 0·012.

Limited Availability. So far it has been assumed that all the selectors of one stage are accessible from each of the selectors of the previous rank, i.e. that full availability conditions exist. These conditions do not often occur in practice. The number of 1st selectors in even a small automatic exchange is usually greater than the number of bank contacts of the subscribers' uniselectors which give access to them. Similarly, the number of 2nd selectors is often greater than the number of contacts of the particular level of the 1st selectors. If, in any system of interconnecting, it is not possible for each selector to obtain access to *all* switches of the next rank, then *limited availability* conditions are said to exist. The term *availability* when used alone denotes the number of trunks to which a selector has access on any one route. Thus a 24-contact uniselector has an availability of 24—irrespective of the number of 1st selectors in the exchange. Similarly, a group selector with 10 outlets per level is said to have an availability of 10.

Limited availability conditions can perhaps best be illustrated by considering an extension of the simple trunking scheme illustrated in Fig. 29. Under the full availability conditions shown, the traffic from a total of 100 subscribers can be carried by a single group of 10 1st selectors. Such an arrangement will carry somewhat more than 3 T.U. If now it is assumed that the exchange increases in size so that there are 200 subscribers' uniselectors, the original 10 1st selectors will not carry the increased traffic of, say, 6 T.U. From the figures given in Table III (Appendix I) it will be seen that, with a full availability group, 15 1st selectors are required to carry a total traffic of 6 T.U. The original full availability conditions can be retained if all the uniselectors in the exchange are provided with 15 contacts so that they can be connected (as shown in Fig. 38) as a single full availability group.

For obvious reasons it is not practicable (or economic) to provide full availability conditions when the traffic, and hence the number of 1st

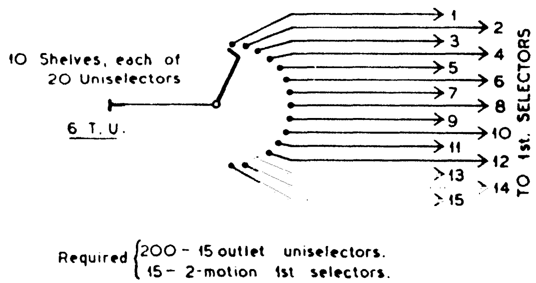


Fig. 38. Full Availability Group to Carry 6 T.U.

selectors, still further increases. Conditions arise, therefore, where it becomes necessary to segregate the traffic into 2 or more separate groups, each group having access to an individual series of 1st selectors. Fig. 39 shows an alternative method of providing for 200 subscribers offering a total traffic of 6 T.U. The subscribers' uniselectors are now divided into 2 groups each of 5 shelves so that each group offers a total traffic of 3 T.U. It is therefore

possible to serve each group by a 10-point uniselector connected direct to 10 1st selectors. Under this scheme 200 uniselectors of a 10-outlet type together with 20 1st selectors will suffice whereas, under the full availability conditions, 200 uniselectors each with 15 outlets and a total of 15 1st selectors are necessary.

The arrangement illustrated in Fig. 39 is a simple example of limited availability conditions. Any one subscriber's uniselector has access to 10 only of the total group of 20 1st selectors. With such a scheme conditions may arise when all 1st selectors accessible from group 1 are engaged, whilst at the same time there may be free selectors associated with group 2. It is to be expected, therefore, that with limited availability more 1st selectors are required than under full availability conditions. In this particular example it may, however, be more economical to provide 20 1st selectors plus 200 uniselectors each of 10 outlets rather than to install 200 uniselectors each of 15 outlets together with 15 1st selectors.

Grading. The use of full availability groups and the alternative of dividing the traffic into separate limited availability groups have so far been considered. Apart from these two methods, it is possible to design various interconnecting schemes which are more efficient than the simple limited availability arrangement but which do not require

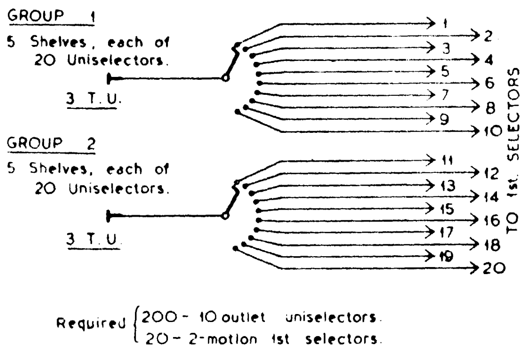


FIG. 39. TWO SEPARATE FULL AVAILABILITY GROUPS WITH 10-POINT UNISELECTORS TO CARRY THE SAME TRAFFIC AS THE 15-POINT SELECTORS OF FIG. 38

the large number of outlets necessary with the full availability scheme. In general, these interconnecting schemes provide for the sources of traffic to be divided into a convenient number of groups, each group having some trunks individual to itself and the remaining trunks shared by a number of groups. It has already been seen that the later choices of individual groups carry a relatively small proportion of the traffic. If, by coupling together the later choices of several groups, it is possible to increase the traffic offered to the later choices then, *provided that the total traffic lost is not greater than the total traffic which would be lost from a system of individual groups*, there will be some increase of efficiency.

The system of interconnecting adopted by the Post Office is known as *grading*. With this system,

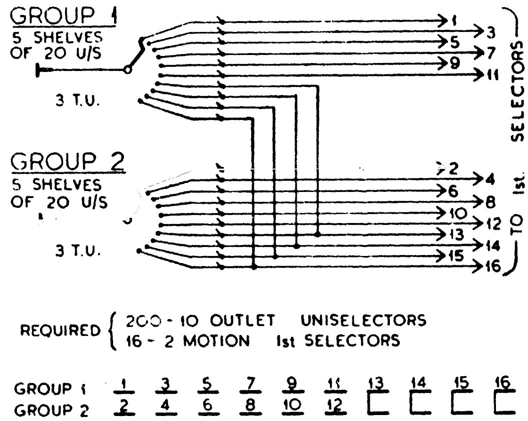


FIG. 40. A SIMPLE EXAMPLE OF THE PRINCIPLE OF GRADING

the sources of traffic are divided into a convenient number of groups, and arrangements are made to provide individual trunks for the early choices of each group with a progressive system of commoning so that traffic from more and more groups is offered to the later choices. Since grading assumes that the traffic offered by each group to the later choices is small, it follows that the trunks of a graded group should always be tested in the same order. It is therefore an essential requirement of grading that the switches shall be of the homing type, i.e. that they shall always search over the trunks in the same order. The use of slipped multiples is, for the same reason, not permissible.

Fig. 40 gives a simple example of the principle of grading. A total traffic of 6 T.U. emanating from a total of 200 uniselectors is assumed. It was shown in Fig. 38 that this traffic requires a total of 15 1st selectors and the use of 15-outlet uniselectors if full availability conditions are to be provided. It was also shown in Fig. 39 that the segregation of the traffic into two limited availability groups with 10-outlet uniselectors involves the provision of 20 1st selectors. In Fig. 40, 10-outlet uniselectors are assumed and the 200 uniselectors are arranged in two groups each offering 3 T.U. The first 6 choices of each group are trunked direct to individual 1st selectors, whilst the remaining 4 outlets of the two groups are commoned

together and trunked to a further 4 1st selectors. This grading therefore requires a total of sixteen 2-motion 1st selectors together with a total of two hundred 10-outlet uniselectors. It will provide

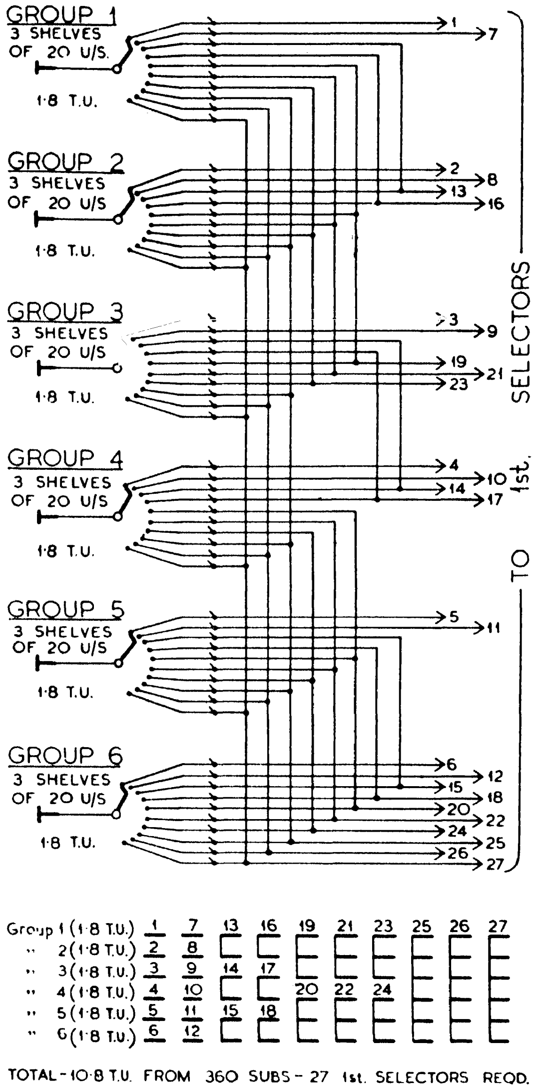


FIG. 41. A MORE PRACTICAL EXAMPLE OF GRADING

the same grade of service as the full availability scheme requiring 15 1st selectors or the simple scheme of separate limited availability groups which requires a total of 20 1st selectors.

Although the graded arrangement is not quite so efficient as a full availability scheme it is nevertheless materially better than the use of separate individual groups. Moreover, this gain of efficiency has been obtained whilst still retaining 10-outlet uniselectors. The conventional method of illustrating a graded group is shown in the lower part of Fig. 40. Ten horizontal lines are drawn to represent the 10 outlets of each group and the vertical connexions between these lines show the commoning between groups. The numbers refer to the 1st selectors to which the various outlets are trunked.

The simple 2-group grading considered above is not truly representative of the principle of grading since it does not show the method of *progressive* commoning. Fig. 41 shows a further and more practicable development of the principle of grading. The number of subscribers has now been increased to 360 and the uniselectors are arranged as six groups each serving three shelves of 20 uniselectors. With the same traffic per subscriber, each group presents to the grading 1·8 T.U., i.e. a total of 10·8 T.U. for the whole grading. With this volume of traffic, a good grading will require 27 trunks to 1st selectors for the standard grade of service. The lower portion of Fig. 41 shows that individual trunks are provided for the first 2 outlets of each group, the 3rd and 4th outlets are common to two groups, the 5th, 6th, and 7th outlets are commoned to three groups, whilst the remaining 3 outlets are commoned to all groups in the grading. Thus, whilst separate trunks are provided for the first outlets, the groups are progressively commoned together until the last choices are common to all groups.

It has been seen that in a 2-group grading there can be individuals and commons, whilst in a 6-group grading it is possible to arrange individuals, pairs, threes and commons (sixes). In the same way, an 8-group grading may contain individual trunks, pairs, fours and commons, and a 12-group grading provides still further possibilities of progressive commoning by the use of individuals, pairs, threes, fours, sixes and commons (twelves). It is usual in the design of gradings to arrange the sources of traffic so that the traffic offered by each group in the grading is substantially equal. Normally there is an even number of groups in every grading owing to the difficulty of arranging progressive commoning for an odd number of groups (e.g. with a 5-group grading it is possible to have only individuals and commons if a balanced arrangement is to be retained).

Traffic Capacity of a Graded Group. The calculation of the traffic capacity of a graded group by strict mathematical analysis is somewhat involved, but a satisfactory approximation can be obtained by the application of Erlang's theory for a full availability group. Briefly, the method is based on the assumption that the traffic carried by any

contact in a grading depends solely on the position of the contact in the grading and on the total traffic offered to the grading, and is independent of the number of sources from which this traffic originates.

Fig. 42 shows a simple grading consisting of 4 groups with an availability of 10 which is served by 23 trunks. For purposes of explanation it is assumed that 2·5 T.U. is offered to each group of the grading, i.e. the total traffic offered is 10 T.U. The traffic carried by the first 3 contacts of group 1 can be readily calculated from a direct application of Erlang's theory, viz.:

Traffic offered to 1st contact = 2·5 T.U.
,, ,, 2nd ,, = 1·78 T.U.
,, ,, 3rd ,, = 1·18 T.U.
,, ,, 4th ,, = 0·705 T.U.

The traffic carried by the 1st contact is the difference between the total traffic offered to it and the traffic passed on to the 2nd contact. Similarly, the traffic carried by the 2nd contact is the difference between the traffic offered to that contact and the traffic passed on to the 3rd contact. Hence the traffic carried by the first 3 contacts is:

Traffic carried by 1st contact = 0·720 T.U.
,, ,, 2nd ,, = 0·600 T.U.
,, ,, 3rd ,, = 0·475 T.U.

Groups 1 and 2 are commoned together at the 4th contact so that the total traffic offered to the 4th contact is 0·705 T.U. from group 1 and 0·705 T.U. from group 2—a total of 1·41 T.U. It is now assumed that the traffic carried by this 4th contact is the same as if the contact were the 4th choice in a full availability group where the originating traffic is such as to offer 1·41 T.U. to the 4th choice. The value of the equivalent originating traffic for a full availability group can readily be determined either from Erlang's equation or, more simply, from the curves illustrated in Fig. 31. In order to offer 1·41 T.U. to the 4th choice of a full availability group, the originating traffic must be 3·51 T.U. The traffic offered to contacts 5, 6, 7, and 8 can now be calculated on the assumption that the originating traffic is 3·51 T.U. i.e.:

Traffic offered to 5th contact = 0·915 T.U.
,, ,, 6th ,, = 0·545 T.U.
,, ,, 7th ,, = 0·290 T.U.
,, ,, 8th ,, = 0·14 T.U.

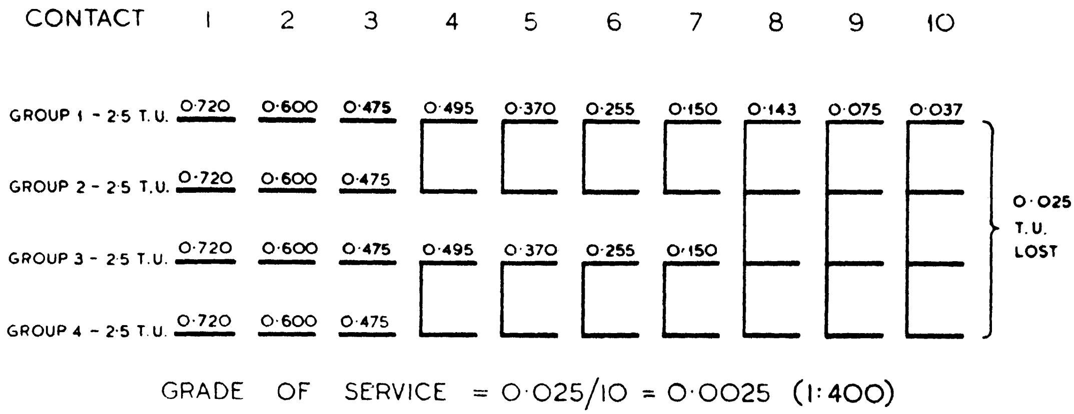


FIG. 42. TYPICAL DISTRIBUTION OF TRAFFIC OVER THE OUTLETS OF A GRADED GROUP

As before, the traffic carried by the 4th contact can be determined by the difference between the traffic offered to the 4th contact and the traffic passed on to the 5th contact, and so on. Hence:

Traffic carried by 4th contact = 0·495 T.U.
,, ,, 5th ,, = 0·370 T.U.
,, ,, 6th ,, = 0·255 T.U.
,, ,, 7th ,, = 0·150 T.U.

The total traffic offered to the 8th contact is the sum of the traffic passed on from all 4 groups, i.e.:

Total traffic offered to 8th contact = 0·14 × 2 = 0·28 T.U. A further application of Erlang's formula shows that a full availability group with an originating traffic of 4·1 T.U. offers to its 8th contact 0·28 T.U. An equivalent originating traffic of 4·1 T.U. therefore offers the following traffic:

Traffic offered to 9th contact = 0·137 T.U.
,, ,, 10th ,, = 0·062 T.U.
,, ,, 11th ,, = 0·025 T.U.
(if such a contact were available).

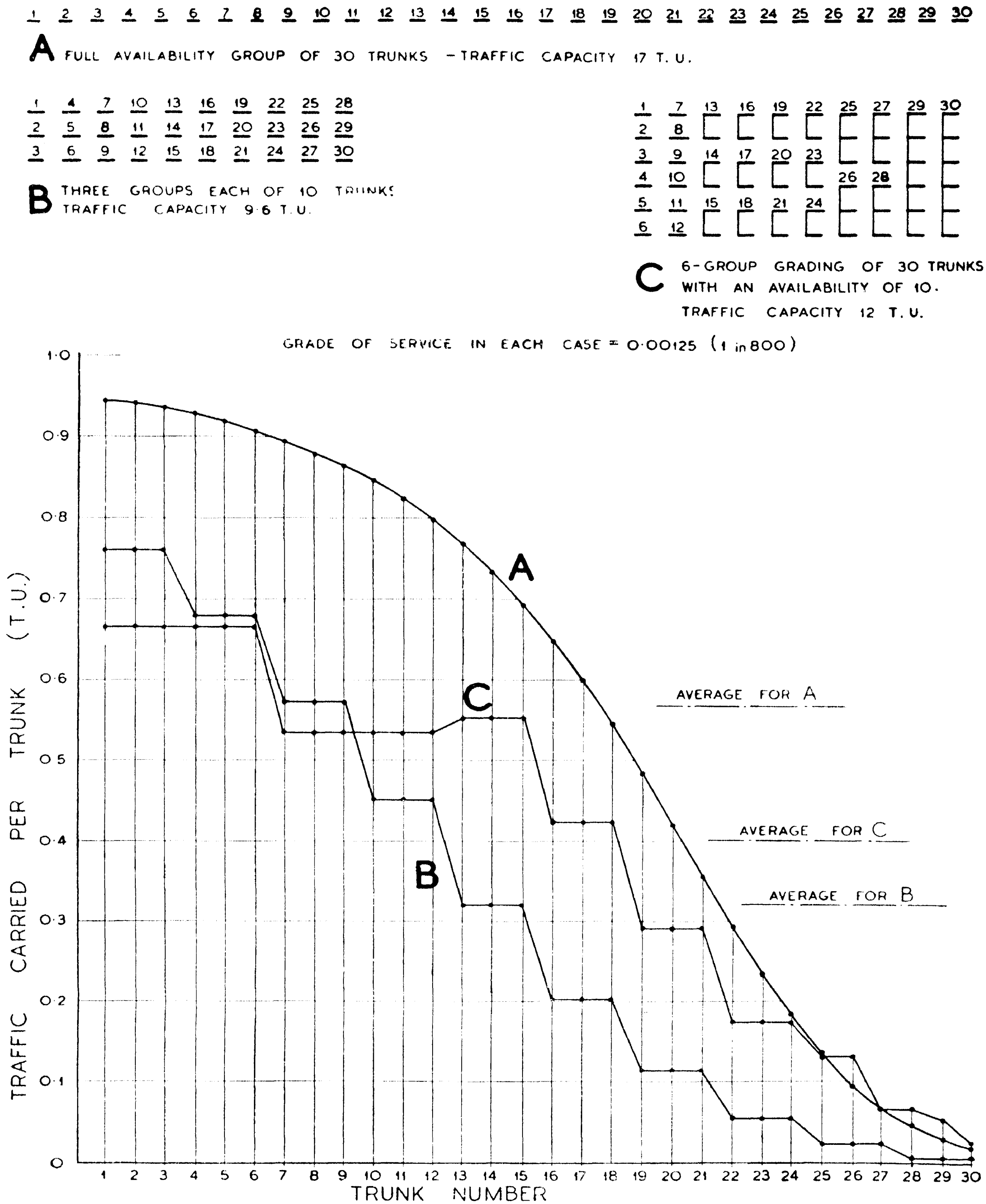


FIG. 43. COMPARATIVE EFFICIENCY OF FULL AVAILABILITY AND GRADED GROUPS

From which:

Traffic carried by 8th contact = 0·143 T.U.
,, ,, 9th ,, = 0·075 T.U.
,, ,, 10th ,, = 0·037 T.U.

It is possible by this means to calculate the traffic carried by each trunk in the graded group and also the total traffic capacity of the grading by adding together the traffic carried by the individual trunks.

The grade of service is the ratio of the traffic passed on from the 10th contact of the grading to the total traffic offered to the grading, i.e.:

Grade of service = 0·025/10
= 0·0025 (1 : 400)

The above method of computing the traffic capacity of a grading is not entirely sound, due to the fact that the distribution of traffic when the calls originate from several groups is not the same as the distribution when the same volume of traffic is offered to a single full availability group.

When the traffic is applied to 2 groups, for example, there may be 2 simultaneous calls (during certain periods) connected to the first choice of each group, but in the full availability case it is not possible to have more than one call at a time on any outlet. Nevertheless, tests with artificial traffic have shown that the approximate method of calculation is in reasonably close agreement with practical conditions.

Efficiency of Gradings. Although the adoption of grading materially increases the efficiency of limited availability groups, it does not, of course, give the efficiency of a full availability scheme. It is interesting to compare the traffic capacity of graded groups with that of comparable full availability conditions. In Fig. 43 the traffic carried by each switch in a group of 30 1st selectors has been calculated for three alternative trunking schemes. At A the 30 selectors are arranged as a full availability group which requires the use of 30-outlet uniselectors. At B the selectors are divided into three separate limited availability groups of 10; 10-outlet uniselectors now being required. The third alternative (C) shows a 6-group grading with an availability of 10 and a total of 30 trunks. The curves illustrate the traffic carried by each selector under each of the three schemes. It will be observed that the traffic carried by all except the very late choice selectors is greatest in the full availability case. Similarly, the traffic carried by the first 9

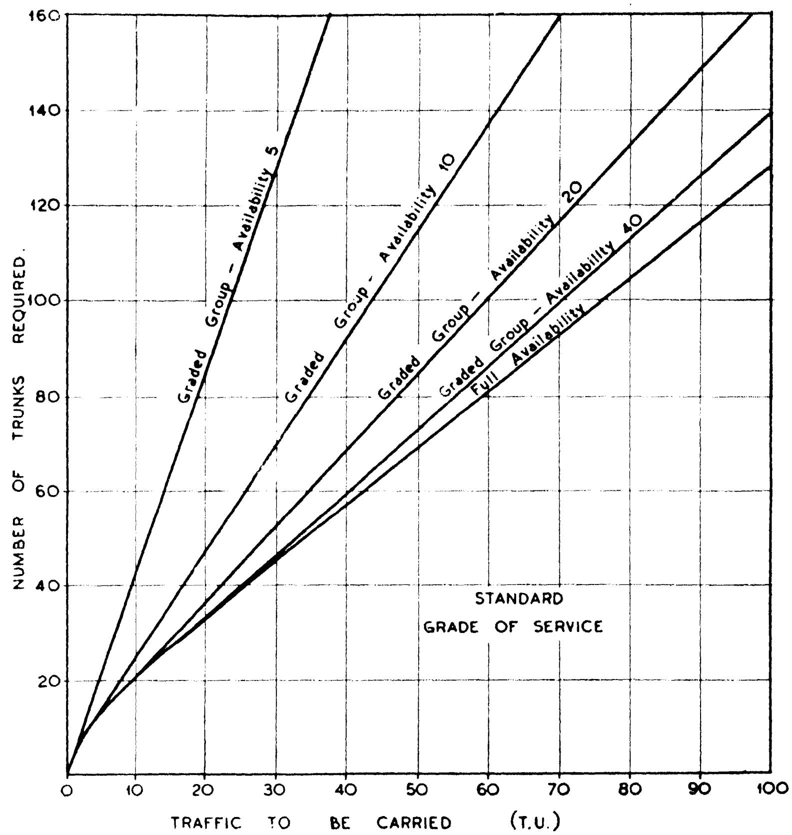


FIG. 44. EFFECT OF AVAILABILITY ON THE NUMBER OF TRUNKS REQUIRED TO CARRY VARIOUS VOLUMES OF TRAFFIC

selectors is somewhat greater with arrangement B than with the graded group. This is to be expected since the total traffic is divided into 6 groups under arrangement C as compared with 3 groups under arrangement B. The increased efficiency of the graded group is in respect of the later choices where curve C is appreciably higher than curve B.

The total traffic capacity of each of the three arrangements is proportional to the area enclosed by the curves. The total traffic capacity of the full availability group is approximately 17 T.U., the graded group will carry 12 T.U., whilst the three separate limited availability groups will carry only

a total traffic of 9·6 T.U. If the total traffic carried is divided by the total number of trunks, the result is the average traffic per trunk. The average values are shown in Fig. 43 and illustrate the relative efficiencies of the three methods of interconnecting.

The number of outlets, i.e. the availability, has a large influence upon the efficiency of a graded

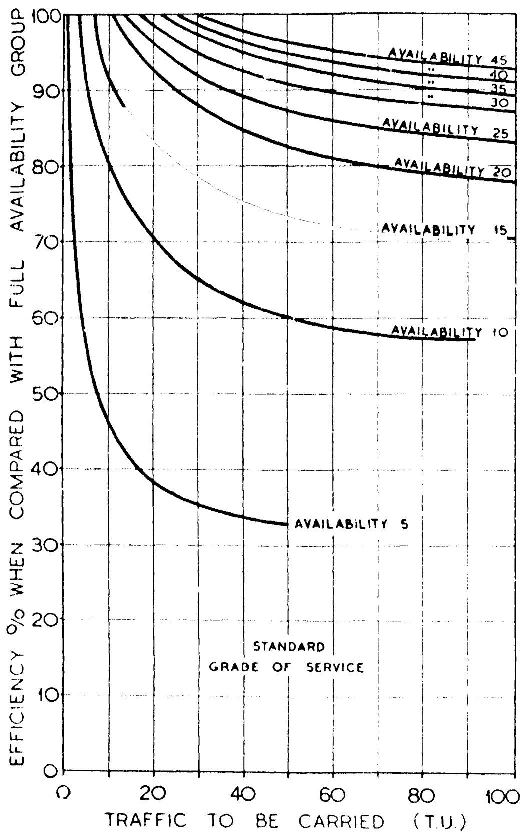


FIG. 45. EFFICIENCY OF GRADED GROUPS WITH VARIOUS AVAILABILITIES

group. If, for example, a total of 30 trunks to the next switching stage is required, it is reasonable to expect that a grading with, say, 20 outlets per group will be more efficient than a similar grading with only 10 outlets per group. The larger the number of outlets, then more nearly does the grading approach the full availability condition. It must be remembered, however, that although an increase in the availability produces a more efficient grading, the resultant saving of selectors must be weighed against the additional cost of the greater capacity banks of the preceding stage. For a specified number of sources of traffic and a known volume of traffic there is an optimum number of outlets which will theoretically give the most economical arrangement.

Fig. 44 shows the number of trunks required to carry a known volume of traffic. Separate curves show the trunks required under full availability conditions and with graded groups of various availabilities. For a total traffic of, say, 10 T.U. there is very little difference in the number of trunks required if the availability is increased beyond 10. For greater volumes of traffic, on the other hand, an increase in the availability from 10 to 20 produces a material saving in the number of trunks required, but even at large volumes of traffic there is very little advantage in increasing the availability of graded groups beyond 40.

Fig. 45 shows somewhat more clearly the relative efficiencies of graded groups of various availabilities as compared with the full availability condition. The efficiency has been expressed as a percentage relative to the full availability case. It is clear from this illustration that with a total traffic of 10 T.U. the efficiency of a graded group with an availability of 5 is only some 46 per cent. With the same traffic, a graded group with an availability of 10 has an efficiency of some 80 per cent. With a total traffic of 50 T.U. a graded group with an availability of 10 has an efficiency of some 60 per cent, whilst the efficiency is increased to 82 per cent, 91 per cent and 95 per cent when the availability of a graded group is increased to 20, 30, and 40 respectively. In practice, the gain of efficiency when the availability is increased above 20 or 30 is so slight that it does not compensate for the additional cost of providing the requisite number of outlets in the preceding stage.

It has already been stated that the theoretically best arrangement varies with the volume of traffic and with the number of sources from which this traffic originates. Ideally it would be desirable to provide switch mechanisms where the availability could readily be adjusted to meet the particular conditions existing. The Strowger 2-motion selector, which is the basic unit of the switching system in this country, does not, however, give facilities for adjusting the availability between the various levels. For purposes of standardization the number of outlets per level is restricted to 10, and hence the trunking arrangements from such selectors are based on an availability of 10. For large volumes of traffic, however, the circuit is arranged to provide dual testing over two banks, thereby increasing the availability to 20. As will be seen later, subscribers' uniselectors are of the 25-contact type which provide 24 outlets and a home position.

Alternative Gradings. In a simple 2-group grading it is easy to determine the arrangement of

the grading if the availability and the total number of trunks are known. Consider a 2-group grading with an availability of 10 which requires a total of 14 trunks to the next stage. The outlets from the 2 groups can be connected either as individual trunks to 1st selectors or corresponding outlets from both groups can be commoned together and served by a single trunk to the next switching. If:

a = the number of outlets connected individually to trunks,

b = the number of outlets commoned to both groups sharing the same trunk, then

$$2a + b = 14 \qquad (1)$$

(the total number of trunks)

Moreover,

$$a + b = 10 \text{ (the availability)} \qquad (2)$$

Subtracting (2) from (1),

$$a = 4$$

and from (2)

$$b = 10 - 4 = 6$$

The required grading therefore consists of the first 4 outlets connected to individual trunks and the last 6 choices commoned to both groups. No alternative arrangement is permissible with a 2-group grading.

For larger gradings the arrangement of individuals, pairs, fours and so on, can be determined by the same method but in all cases except 2-group gradings there are a number of alternative arrangements all of which will meet the required conditions. In a 6-group grading, for example, it is possible to arrange the contacts either as individuals, pairs, threes or sixes (commons). Adopting the same procedure as before, if:

a = the number of outlets which are connected individually to trunks,

b = the number of outlets which are connected together to form pairs,

c = the number of outlets connected together to form threes,

d = the number of outlets where all groups of the grading are commoned,

then, with an availability of 10:

$$a + b + c + d = 10 \qquad (3)$$

Moreover, if the total number of trunks to serve the grading is, say, 31, then:

$$6a + 3b + 2c + d = 31 \qquad (4)$$

There are now 4 unknowns but only 2 equations and hence a single solution is not possible. The calculation can nevertheless be simplified by extracting from the 2 equations as much information as possible. For example, if Equation (3) is subtracted from Equation (4) d is eliminated and the following equation results:

$$5a + 2b + c = 21 \qquad (5)$$

It is apparent from Equation (3) that a, b, c, or d can never exceed 10. Similarly from Equation (5) a cannot be greater than 4 (this would occur if b and c together were 1).

$$\text{If } a = 4,\quad 2b + c = 1 \qquad (6)$$
$$\text{If } a = 3,\quad 2b + c = 6 \qquad (7)$$
$$\text{If } a = 2,\quad 2b + c = 11 \qquad (8)$$
$$\text{If } a = 1,\quad 2b + c = 16 \qquad (9)$$
$$\text{If } a = 0,\quad 2b + c = 21 \qquad (10)$$

All the possible values of b and c for Equations (6), (7), (8), (9), and (10) can be evaluated by substituting all permissible values of b and then working out the corresponding values of c. It is then a very simple matter to determine from Equation (3) the values of d for the various values of a, b, and c. The results are shown in Table III on page 48.

When $a = 4$, $2b + c$ (the 2nd column) is 1. There is only one tenable value of b (i.e. 0) to meet this condition and hence c is 1 and the corresponding value of d is 5. Similarly, when $a = 3$ (Equation (7)), the value of $2b + c$ is 6 and there are 4 possible values of b, i.e. 3, 2, 1, 0. There are 4 corresponding values of c and d. The same procedure is adopted for the other possible values of a and it is readily possible to determine the corresponding values of b. The permissible grading arrangements for a total of 31 trunks are shown in heavy type in Table III. There are, in all, 10 alternative arrangements, all of which give 31 trunks.

The same procedure can be adopted for larger gradings but the calculations become a little more laborious when the number of alternative groupings becomes greater. In a 16-group grading, for example, it is possible to have individuals, pairs, fours, eights and commons. If:

a = the number of individuals,

b = the number of pairs,

c = the number of fours,

d = the number of eights,

e = the number of commons,

then, if the total number of trunks is, say, 50:

$$a + b + c + d + e = 10 \qquad (11)$$
$$16a + 8b + 4c + 2d + e = 50 \qquad (12)$$

Subtracting (11) from (12):

$$15a + 7b + 3c + d = 40$$

Hence a can have values of 0, 1 or 2, but cannot be greater than 2.

$$\text{If } a = 2,\ 7b + 3c + d = 10 \qquad . (13)$$

$$\text{If } a = 1,\ 7b + 3c + d = 25 \qquad . (14)$$

$$\text{If } a = 0,\ 7b + 3c + d = 40 \qquad . (15)$$

From Equation (13), b cannot be greater than 1.
From Equation (14), b cannot be greater than 3.
From Equation (15), b cannot be greater than 5.

The values of b, c, and d for the 3 alternative values of a can now be determined as described in the previous paragraph.

TABLE III

ALTERNATIVE ARRANGEMENTS OF A 31-TRUNK GRADING WITH AN AVAILABILITY OF 10

(Permissible alternatives in heavy type)

Individuals a	$2b + c$ $(= 21 - 5a)$	Pairs b	Threes c	Commons d $(10 - a - b - c)$
4	1	**0**	**1**	**5**
3	6	**3**	**0**	**4**
		2	**2**	**3**
		1	**4**	**2**
		0	**6**	**1**
2	11	**5**	**1**	**2**
		4	**3**	**1**
		3	**5**	**0**
		2	7	—
		1	9	—
		0	—	—
1	16	**8**	**0**	**1**
		7	**2**	**0**
		6	4	—
		5	6	—
		4	8	—
		3	—	—
		2	—	—
		1	—	—
		0	—	—
0	21	10	1	—
		9	3	—
		8	5	—
		7	7	—
		6	9	—
		5	—	—
		4	—	—
		3	—	—
		2	—	—
		1	—	—
		0	—	—

Best Gradings. Since in all but 2-group gradings there are a number of alternative arrangements to provide the same total number of trunks, it is necessary to decide which of the possible alternatives will produce the best grading arrangement. It can be shown by theoretical calculations and by the results of practical tests with artificial traffic that the most efficient grading is the one in which there is a smooth progression of the choices from individuals to the partial commons, partial commons to larger partial commons and the larger partial commons to full commons. In a 6-group grading with an availability of 20 and a total of 60 trunks, for example, the most efficient arrangement is the one in which the first 5 outlets are connected as individuals, the second 5 as pairs, the third 5 as threes and the last 5 outlets as commons.

In most practical cases it is not possible for the number of choices of each type to be the same as in this example, but for a specified number of trunks and groups there is one particular grading arrangement which is more satisfactory than the others. The grading to be adopted should be the one which gives the minimum sum when the successive differences in the number of choices of one type are subtracted from the number of choices of the next type (without respect to the signs). It has been shown that with a 6-group grading with 31 trunks and an availability of 10 there is a total of 10 alternative grading arrangements. These alternatives are scheduled in Table IV, and for each alternative the differences between the number of individuals and pairs, pairs and threes, and threes and commons are added together to give a total for each alternative which represents the sum of successive differences. Alternative C gives the minimum sum of successive differences and is the best grading with the specified conditions.

TABLE IV

METHOD OF CHOOSING THE OPTIMUM FORMATION OF A GRADING

(Best grading shown in heavy type)

Six-group Grading—Availability 10—Trunks 31

Alternative	A	B	C	D	E	F	G	H	I	J
Number of Individuals .	4	3	**3**	3	3	2	2	2	1	1
Number of Pairs . .	0	3	**2**	1	0	5	4	3	8	7
Number of Threes . .	1	0	**2**	4	6	1	3	5	0	2
Number of Commons . .	5	4	**3**	2	1	2	1	0	1	0
Sum of Successive Differences	9	7	**2**	7	14	8	5	8	16	13

It is interesting to see the difference between the various alternatives as measured by the grade of service which they give for the same total traffic

offered. Fig. 46 shows the ten alternative arrangements for the grading considered above and for each alternative the grade of service has been calculated for a total traffic of 13·2 T.U. The right-hand portion of Fig. 46 confirms that alternative C is the best grading, but it will be observed that there is very little to choose in this particular case between gradings B, C, and D. Alternatives I and J are by far the worst, due to the fact that the system of commoning does not progress smoothly as in most of the other alternatives.

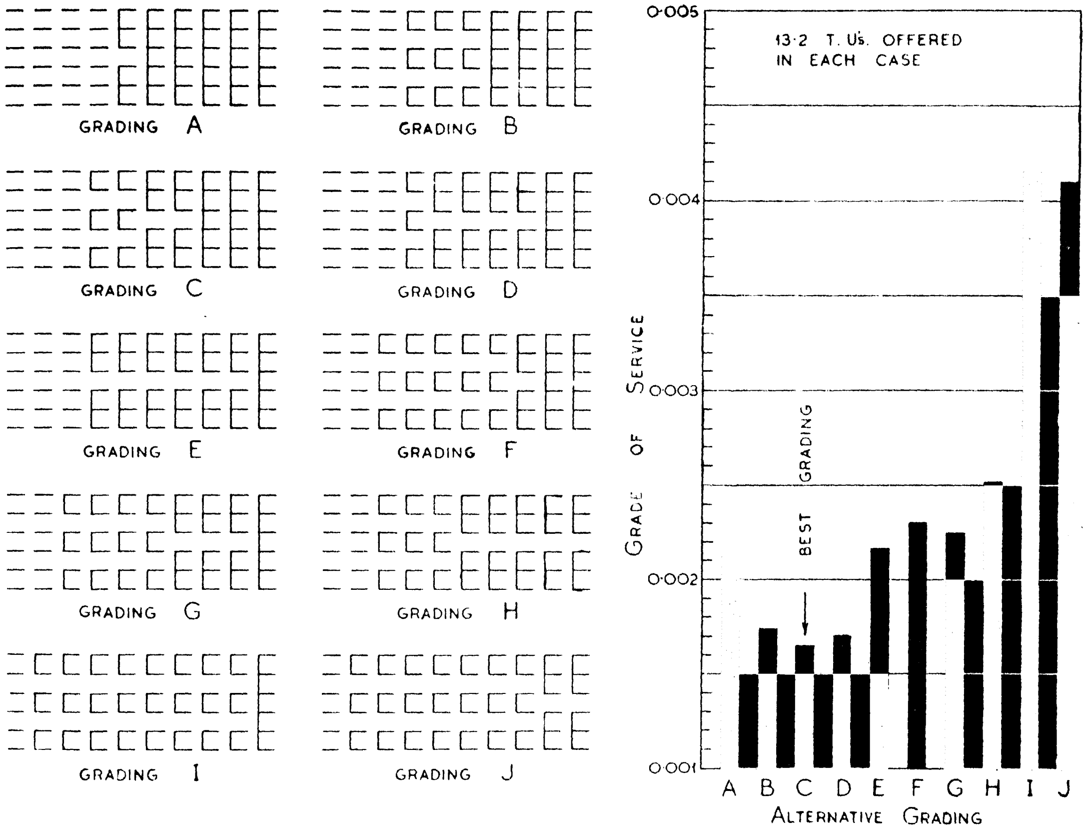


Fig. 46. Relative Efficiency of Alternative Gradings with the Same Number of Trunks

Transposition Method of Determining Best Gradings. The semi-algebraic method of determining the possible alternative grading arrangements and the method of selecting the smoothest grading as described on preceding pages, is apt to become somewhat laborious, especially for gradings containing a large number of groups with availabilities of 20 or 24. The following method will be found useful for obtaining a smooth grading arrangement without the necessity of investigating all the various possible alternative combinations. The principle of the method is illustrated in Table V. The 6-group grading with 31 trunks and an availability of 10 (as considered in Table III) is assumed for purposes of illustration. With a 6-group grading it is possible to have individuals, pairs, threes and commons. The number of trunks per outlet of each type is entered at the head of the tabulation (e.g. 6, 3, 2, and 1 respectively), and the change in the number of trunks resulting from the conversion of one partial common to the adjacent partial common of a higher or lower order is calculated. For example, with a 6-group grading there are 6 trunks per outlet for individuals and 3 trunks per outlet when the groups are paired. If an individual outlet is therefore converted to a paired outlet, there is a loss of $6 - 3 = 3$ trunks. Similarly, if in the 6-group grading an outlet, where the groups are paired, is converted to an outlet where the groups are commoned together in threes, there is a loss of $3 - 2 = 1$ trunk.

The smoothest possible grading—irrespective of the number of trunks involved—is now entered in the tabulation. In a 6-group grading there are 4 possible commoning arrangements and, when the availability is 20, the smoothest possible grading occurs when 5 of the outlets are connected as individuals, 5 as pairs, 5 as threes, and 5 as commons. In this case, the sum of successive differences is 0. If the same grouping is applied to a grading with an availability of 10 (Table V), then

TABLE V

DETERMINATION OF BEST ARRANGEMENT FOR A 6-GROUP GRADING WITH 31 TRUNKS AND AN AVAILABILITY OF 10

Trunks per Outlet			6	3	2	1	Sum of Successive Differences
Change per Transposition				3	1	1	
			a	b	c	d	
Transposition	Change in Number of Trunks	Total Trunks	Individuals	Pairs	Threes	Commons	
		27	2	2	3	3	1*
c to a	+ 4	31	3	2	2	3	2

* Smoothest possible grading irrespective of number of trunks.

the smoothest possible arrangement occurs when there are 2 individuals, 2 pairs, 3 threes, and 3 commons. (The reverse arrangement (3, 3, 2, 2) is equally as smooth, and either grading will suffice for the purpose.) This gives a sum of successive differences of 1, and with the 2, 2, 3, 3 arrangement, it provides 27 trunks. In the example given, it is assumed that 31 trunks are required. The ideal grading (2, 2, 3, 3) can be modified to give more trunks by reducing the number of full or partial commons, and increasing the individuals or commons of a lower order by the same amount. If one paired outlet (*b*) is moved over to an individually connected outlet (*a*), there is a gain of 3 trunks. Similarly, a change from a 3-common to a paired outlet increases the number of trunks by 1, and so on. Thus, if *d* is decreased by 1, and the freed outlet is transposed to *a*, there is a gain of $1 + 1 + 3 = 5$ trunks. Similarly, a transfer of one *c* trunk to an *a* trunk increases the capacity of the grading by 4 trunks, and so on. It is therefore possible by transposing from one column to another to increase or decrease the number of trunks of the grading, whilst still maintaining the same total number of outlets per group (i.e. the same availability).

The best possible grading in Table V occurs when the outlets are arranged as 2, 2, 3, and 3. The transpositions are so made that

(*a*) they increase or decrease the size of the grading until the correct number of trunks is obtained;

(*b*) there is a minimum difference between the lowest and highest number of outlets of each type.

In Table V the ideal 27-trunk grading can readily be converted into a 31-trunk grading by making one transposition from *c* to *a*, i.e. so that there are 3 individuals, 2 pairs, 2 threes and 3 commons. This produces a sum of successive differences of 2, and is the best possible arrangement with 31 trunks.

TABLE VI

DETERMINATION OF BEST ARRANGEMENT FOR A 30-GROUP GRADING WITH 200 TRUNKS AND AN AVAILABILITY OF 20

Trunks per Outlet			30	15	10	6	5	3	2	1	Sum of Successive Differences
Change per Transposition				15	5	4	1	2	1	1	
			a	b	c	d	e	f	g	h	
Transposition	Change in Number of Trunks	Total Trunks	Individuals	Pairs	Threes	Fives	Sixes	Tens	Fifteens	Commons	
		155	2	2	2	2	3	3	3	3	1*
e to a	+ 25	180	3	2	2	2	2	3	3	3	2
f to b	+ 12	192	3	3	2	2	2	2	3	3	2
g to c	+ 8	200	3	3	3	2	2	2	2	3	2

* Smoothest possible grading irrespective of number of trunks

The best arrangements for small gradings can often be made with a single transposition as shown above. In very large gradings it may be necessary to carry out several successive transpositions to attain the required number of trunks. A very large and complex grading is considered in Table VI. A 30-group grading with 200 trunks and an availability of 20 is assumed. With such a grouping it is possible to have 8 alternative arrangements of individuals, partial commons and commons. The ideal grading occurs with a 2, 2, 2, 2, 3, 3, 3, 3 arrangement, which gives a value of 1 for the sum of successive differences and a total trunk capacity of 155. A single transposition from *e* to *a* increases the capacity of the grading by $1 + 4 + 5 + 15$

= 25 trunks (i.e. to 180), whilst a further transposition from *f* to *b* increases the capacity by an additional 12 trunks (i.e. to 192), and the further 8 trunks can be obtained by transposing from *g* to *c*. The resultant grading has the required capacity can be obtained, but the amount of work involved is very much less than if an attempt is made to evaluate all the various possible combinations, and then to find the smoothest arrangement. The results can be readily checked by trying out further

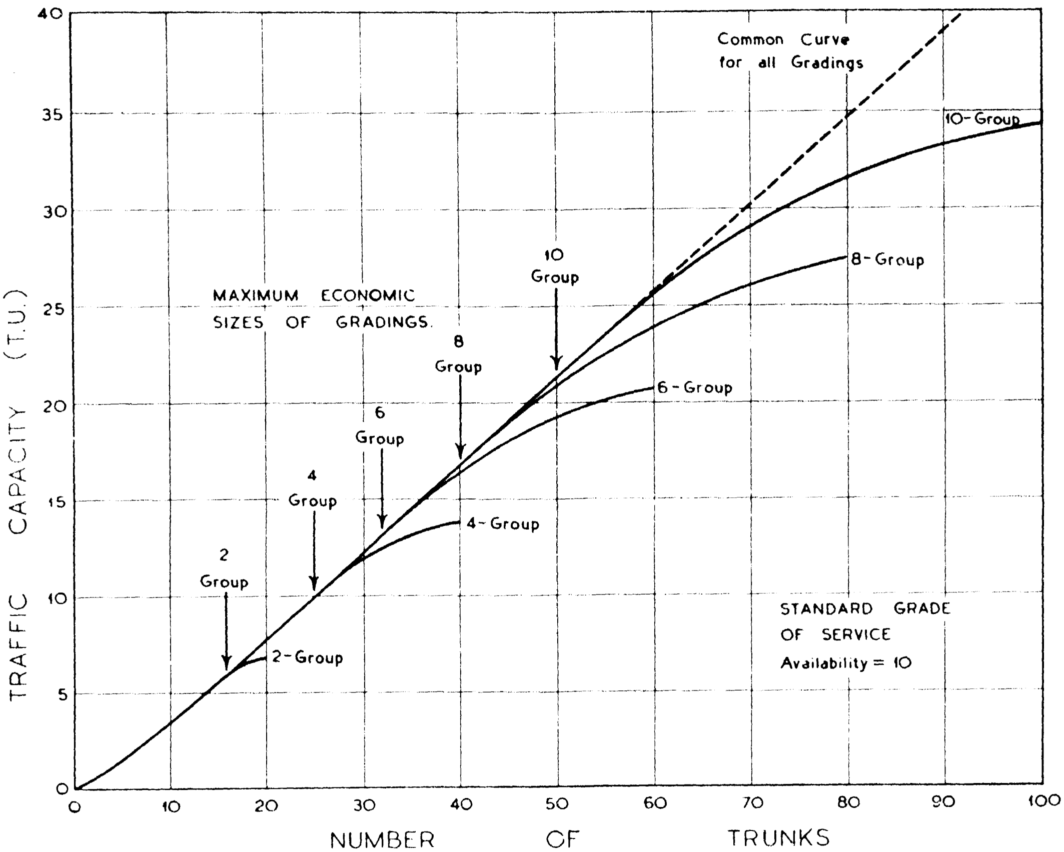


FIG. 47. SHOWING THE OPTIMUM SIZE OF GRADED GROUPS

of 200 trunks and the sum of successive differences is kept down to 2.

A number of gradings can be solved whilst still retaining the same range of outlet groupings as the ideal grading (i.e. between 2 and 3 in Tables V and VI). The important point to remember is that the range should not be increased until the maximum number of transpositions has been made. When it becomes necessary to increase the range (e.g. down to 1, or up to 4) then the maximum number of transpositions must again be made before the range is further widened.

With a little practice the transpositions can be carried out whilst still maintaining the smoothest possible grading arrangement. A complex case may require several steps before a satisfactory solution transpositions such that the correct number of trunks is maintained.

Optimum Size of a Graded Group. The efficiency of any grading depends, to some extent, upon the number of groups in the grading. In any given circumstances there is an optimum size for a grading which will give the highest efficiency and the most suitable practical arrangement. If the traffic capacities of various gradings are calculated, it will be found that with a given number of groups there is a maximum number of trunks beyond which the efficiency of the grading rapidly declines. Fig. 47 shows the traffic capacities of 2-group, 4-group, 6-group, 8-group, and 10-group gradings. An availability of 10 and the standard grade of service are assumed. Up to about 15 trunks the traffic

capacity of each of the gradings is the same. When the number of trunks is increased to 20, then the 4-group, 6-group, etc., gradings have a higher traffic capacity than the 2-group grading. Similarly, if the number of trunks is increased to, say, 50, then the 10-group grading is more efficient than the 8-group, 6-group and smaller gradings. These results are, of course, to be expected since when the number of trunks in any one grading increases above a certain value, the degree of commoning decreases rapidly and the grading approaches the condition of separate limited availability groups. A 6-group grading with an availability of 10, for example, is no longer a grading in the accepted sense when the total number of trunks reaches 60. The trunking under these conditions is that of six separate limited availability groups each of 10 trunks. Similarly, when 50 trunks are to be provided from a 6-group grading the amount of commoning is small and the traffic capacity can be expected to be less than that of a 50-trunk grading with a larger number of groups and hence a more smooth progression of commoning. It is clear, therefore, that from the point of view of efficiency there is a maximum number of trunks for any grading of a specified number of groups.

It will be noted that if the number of trunks is limited in this way it is possible to obtain a common curve for all gradings which will show the relationship between the number of trunks and the traffic capacity—irrespective of the number of groups in the grading. This is a great advantage for design work and avoids the necessity of separate tables for gradings of varying numbers of groups.

Apart from the question of switching efficiency, the number of groups is largely determined by the degree of flexibility required. A large number of groups provides a grading which can readily be modified to cater for future growth and changes in traffic. On the other hand, a large number of groups may increase the cabling costs of an exchange. Moreover, gradings are in practice limited by maintenance considerations. With very large gradings the later choices are accessible from a large number of switches in the preceding stage, and if this number is too great difficulties occur in tracing calls backwards through the equipment. To cater for this aspect, gradings are usually limited to a maximum of some 250 trunks.

With large gradings there are, particularly on the later choices, a large number of bank contacts and the associated wiring connected in parallel and it becomes necessary to limit the size of graded groups to keep the volume of cross-talk within reasonable limits. The limit of cross-talk between any two connexions has been fixed at 500 millionths, and to ensure that the cross-talk is always within this limit the number of bank contacts multipled together on any one choice in a selector grading should not exceed, say, 2000. There are some complications in this respect when two adjacent levels are connected to similar large capacity gradings.

In practice the number of grading groups to be adopted in any particular circumstances is determined from the following empirical formula:

$$g = \frac{2 \times n}{a}$$

where g = number of grading groups,

n = number of trunks,

a = availability.

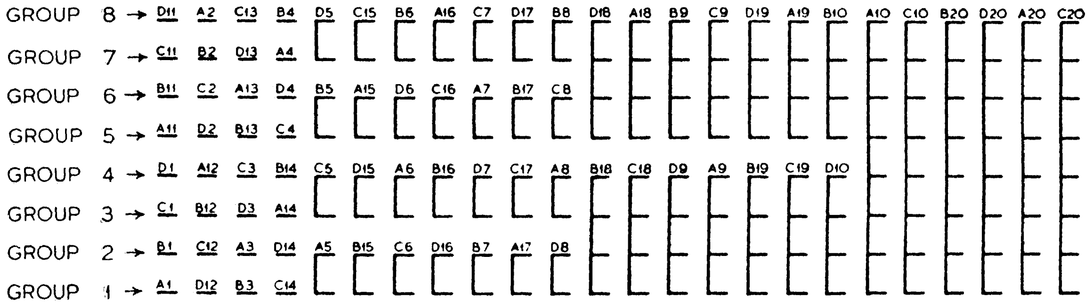
The figure obtained by this formula is the minimum number of grading groups which should be provided in a grading for "n" trunks. The above formula does not, however, apply to 2-, 4-, or 6-group gradings, the maximum number of trunks in these cases being:

No. of Groups	Maximum No. of Trunks			
	Availability			
	10	20	24	40
2	16	32	38	64
4	25	50	60	100
6	32	64	76	128

Allocation of Selectors to a Grading. The allocation of selectors to the trunks of a grading is of some importance. Fig. 48 *A* shows a typical 8-group grading from the banks of 24-outlet subscribers' uniselectors. A total traffic of 50 T.U. from the 8 groups is assumed which (with pure chance traffic) requires 80 trunks from the grading to 1st selectors. It is probable that the volume of traffic on some levels of the 1st selectors will necessitate the grading of the trunks from 1st to 2nd selectors. If it is assumed (as at *C*) that the 80 1st selectors are arranged on 8 shelves of 10 selectors each, then it is convenient to group the 1st selectors into units of 2 shelves, thereby providing a 4-group grading from each level of the 1st selectors. For convenience the 4 groups of 1st selectors have been designated A, B, C, and D. (These should not be confused with the shelf designation letters—see Ch. IV.)

In the first place it is important to equalize as far as possible the traffic from the 4 groups of 1st selectors to allow of a balanced grading to

A - GRADING FROM SUBSCRIBERS' UNISELECTORS.

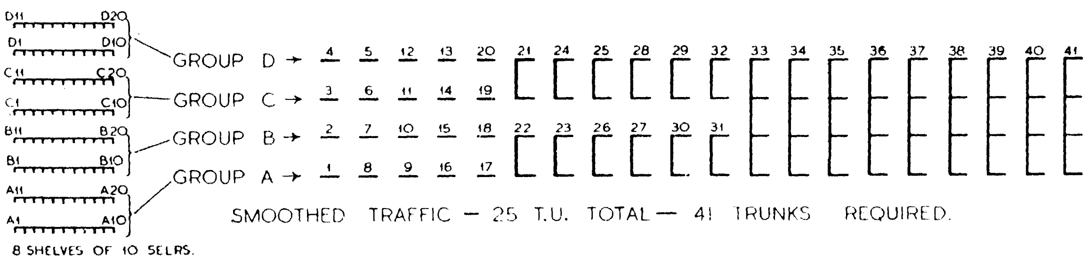


PURE CHANCE GROUP TRAFFIC — 50 T.U. TOTAL — 80 TRUNKS REQUIRED.

B - DISTRIBUTION OF TRAFFIC TO SELECTOR GROUPS.

TRAFFIC OFFERED TO 1ST. SELECTOR GPS } FROM	CHOICES																								TOTAL TRAFFIC (T.U) APPROX
	1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th	10 th	11 th	12 th	13 th	14 th	15 th	16 th	17 th	18 th	19 th	20 th	21 st	22 nd	23 rd	24 th	
GROUP D (SELECTORS D1 – D20)	2	2	2	2	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	0	0	1	0	0	12·5
GROUP C (SELECTORS C1 – C20)	2	2	2	2	1	1	1	1	1	1	1	0	1	0	1	0	1	0	0	1	0	0	0	1	12·5
GROUP B (SELECTORS B1 – B20)	2	2	2	2	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	0	1	0	0	0	12·5
GROUP A (SELECTORS A1 – A20)	2	2	2	2	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	0	0	0	1	0	12·5

C - GRADING FROM ONE LEVEL OF 1ST. SELECTORS.



SMOOTHED TRAFFIC — 25 T.U. TOTAL — 41 TRUNKS REQUIRED.

D-AVAILABILITY, FROM UNISELECTOR GROUPS, OF TRUNKS TO 2ND SELECTORS

TRUNK NUMBER	NO. OF CHOICES IN EACH GROUP FROM WHICH EACH TRUNK IS AVAILABLE.							
	GROUP 1	GROUP 2	GROUP 3	GROUP 4	GROUP 5	GROUP 6	GROUP 7	GROUP 8
1, 8, 9, 16 & 17	6	6	6	6	7	7	6	6
2, 7, 10, 15 & 18	6	6	5	5	6	6	6	6
3, 6, 11, 14 & 19	6	6	7	7	6	6	6	6
4, 5, 12, 13 & 20	6	6	6	6	5	5	6	6
22, 23, 26, 27, 30 & 31	12	12	11	11	13	13	12	12
21, 24, 25, 28, 29 & 32	12	12	13	13	11	11	12	12
33, 34, 35, 36 etc. to 41	24	24	24	24	24	24	24	24

FIG. 48. ALLOCATION OF SELECTORS TO THE OUTLETS OF A GRADING (SHOWING SMOOTHING EFFECT)

2nd selectors. *The most satisfactory way of balancing the traffic between the groups of 1st selectors is to arrange that the first choices of the uniselector grading are equally divided amongst selectors in the 4 groups, and similarly that the 2nd, 3rd, 4th, etc., choices of the uniselector grading are allocated as evenly as possible to all the groups of 1st selectors.* This principle is illustrated at *B* (Fig. 48). It will be noted that 2 trunks from the first choice of the uniselector grading are routed to selectors in each of the 1st selector groups. The second, third, and fourth choices are similarly connected. Groups A, B, C, and D of 1st selectors each have one selector connected to choices 5 to 11 inclusive of the uniselector grading. The later trunks are similarly balanced as far as is possible to provide equal volumes of traffic to the 4 groups of 1st selectors.

It is undesirable from a practical point of view to allocate consecutive choices on any particular group of subscribers' uniselectors to 1st selectors on the same shelf. If consecutive switches on a particular shelf of 1st selectors serve nearby choices of one particular group of uniselectors, then there is a danger of complete breakdown or at the best a serious degradation of service to one uniselector group should a defect occur on one particular shelf of 1st selectors. It is, for example, common practice to serve one shelf of 1st selectors from a common battery supply fuse, and if this fuse should blow it is desirable to arrange that the fault should not seriously affect any particular group of subscribers. In Fig. 48, *A* the first choice of Group 1 is to a selector on the first shelf of the A group, the second choice routes to a selector on the second shelf of the D group, the third choice is via the first shelf of the B group, whilst the fourth choice is served by a selector on the second shelf of the C group. The same system is adopted for all choices in each of the 8 groups forming the uniselector grading.

The allocation of selectors to the trunks of a grading has also a material effect upon the traffic capacity of the subsequent rank of selectors. As will be seen in the next paragraph, it is possible by careful allocation of selectors to obtain a smoothing effect which enables material economies to be made in the number of switches required in subsequent switching stages.

To summarize, selectors are allocated to the trunks of a grading so that as far as possible:

(*a*) The traffic is equally distributed amongst the several groups of selectors in the next switching stage.

(*b*) Consecutive or nearby choices of one particular group in a grading are not trunked to selectors on one shelf of the succeeding stage.

(*c*) *The selectors are allocated to the grading so that each trunk from these selector levels carries* traffic from as many of the original sources as possible. This produces a smoother flow of traffic to the following switching stages.

Smoothed Traffic. It has already been shown that the traffic originating from subscribers is of a pure chance character, i.e. within a specified period of known average traffic the number of calls originating at any one moment is determined by pure chance. The most satisfactory condition for automatic switching occurs when the traffic offered to a given group of selectors is obtained from as many sources as possible. By this means it is likely that momentary periods of heavy traffic from one source may be substantially balanced by a period of light traffic from other sources. This condition is met in all full availability groups, but when the volume of traffic necessitates the introduction of a grading scheme it follows that there is some division of the sources of traffic to form the groups of the grading.

In Fig. 48 *A*, for example, the traffic from a large number of subscribers is divided into 8 separate groups to form an 8-group grading from the subscribers' uniselectors. At any particular instant the traffic from, say, group 1 may be heavy whilst, at the same time, the traffic from group 2 may be comparatively light. With the principle of grading there are certain individual choices from each group whilst the later choices are commoned in a progressive manner. It is quite conceivable that congestion conditions may at some instant occur on group 1 whilst there are disengaged trunks allocated individually to other groups of the grading. An allowance for this condition is, of course, made in the method of determining the total number of trunks required from any graded group.

Irregularities of traffic flow in the various groups of a grading can, to some extent, be smoothed out at the next switching stage by the method of allocating selectors to the trunks of a grading. Fig. 48, diagram *C*, shows a grading from one level of the 1st selectors served from the 8-group uniselector grading. It is assumed for simplicity that 50 per cent of the total traffic (i.e. 25 T.U.) is routed over this particular level. (In practice the traffic is usually more evenly divided amongst the various levels of 1st selectors.) The selectors in groups A, B, C, and D have been allocated to the trunks of the uniselector grading in such a way that any particular trunk from a level of 1st selectors is accessible from as many choices as possible in each of the 8 uniselector groups. This condition is illustrated at *D*. It will be noted that each individual trunk from 1st selectors to 2nd selectors is accessible from approximately 6 choices of each of the

8 uniselector groups. Similarly, trunks to 2nd selectors which are commoned to 2 groups of 1st selectors (e.g. trunk 21) are accessible from some 12 choices of each of the uniselector groups. The final trunks of the 1st selector grading which are commoned to all 4 groups are, of course, accessible from the full 24 choices of each of the uniselector groups.

With this arrangement the traffic offered to 2nd selectors is largely independent of momentary traffic variations between the groups of subscribers' uniselectors. Hence, the traffic to the 2nd selectors is usually of a smoother nature than that offered to the 1st selectors, and advantage is taken of this smoothing of the traffic to effect economies in the number of trunks to 2nd selectors. It is interesting to note that with the smoothed traffic, 41 trunks are required from a selector level to which is offered a total traffic of 25 T.U. Without the smoothing effect, 44 trunks to 2nd selectors would be required, i.e. there is a saving of 3 2nd selectors resulting from a careful allocation of the 1st selectors to the trunks of the uniselector grading. It should be realized, however, that although the traffic offered to the 2nd selectors is more smooth than that offered to the 1st selectors, the traffic is still considerably less smooth than under full availability conditions. If, for example, it was assumed that the uniselectors had full availability to 1st selectors and that each level of the 1st selectors had full availability to all 2nd selectors serving that level, then 69 trunks from uniselectors to 1st selectors and 39 trunks from 1st selectors to 2nd selectors would carry the traffic with the same grade of service.

It is clear from the foregoing that the maximum smoothing effect would be obtained if all the traffic from the subscribers was routed to one particular level of 1st selectors. In practice these conditions do not obtain and the traffic is usually divided into from 2 to 7 separate groups at the 1st selector levels. Under these conditions there is some loss of smoothing effect since at any one instant there may be a momentary surge of traffic on one particular level and a corresponding dearth of traffic on another level of the 1st selectors. The smoothing of traffic obtained at 1st selector levels is also largely lost when this traffic reaches subsequent stages of selection. The traffic from the subscribers' uniselectors may, for example, divide into 7 groups at the 1st selector and each group again divides into, say, 10 groups at the second selector stage. The traffic offered (in a 4-digit scheme) to the final selectors is therefore divided into anything up to 70 separate groups. Similarly the degree of smoothing obtained is dependent to a considerable extent upon the number of trunks and upon the number of groups from which the traffic originates. If, for example, there were only 2 groups in the uniselector grading and, say, 30 trunks, then there is not the same opportunity for smoothing as in, say, a 24-group uniselector grading with a total of, say, 200 trunks.

In practice, smoothing of traffic is assumed to take place only between 24-outlet subscribers' uniselectors and 1st selectors and then only when 70 or more 1st selectors are required to serve the grading. In all other circumstances the traffic is assumed to be pure chance. Table VI of Appendix I shows the traffic capacity of gradings containing from 1 to 100 trunks when the availability is 20 and the grading is offered smooth traffic from a large uniselector grading. The traffic values should be compared with Table V of the same Appendix which shows the comparable conditions for pure chance traffic.

200-outlet Group Selectors. It has been shown in earlier paragraphs that a large group of trunks will carry a greater average traffic per trunk than a smaller group carrying a similar type of traffic. In the full availability case, a group of 10 trunks will carry some 3·43 T.U. with the standard grade of service, thereby giving an average of 0·343 T.U. per trunk. If the trunking arrangements are such that the circuits are arranged in larger groups of 15 trunks, then the traffic capacity is increased to 6·58 T.U. for the same grade of service, i.e. the loading is increased to an average of 0·439 per trunk. Similarly, if the size of the groups is still further increased to 20 trunks, the traffic capacity becomes 9·35 which gives an average loading per trunk of 0·467 T.U. Substantially the same conditions exist on graded groups as has already been demonstrated in Fig. 35.

The basic Strowger switch is essentially a mechanism with 10 contacts on each of 10 levels. When such switches are used as group selectors they normally give a uniform availability of 10 on each level. It would, of course, be possible to design a special mechanism for group selectors which can have, say, 15 or possibly even 20 contacts on each level and to design a circuit which would provide automatic hunting over the full 15 or 20 contacts. Such selectors could not be used as final selectors where the rotary action is under the control of dialled impulses, and the provision of special non-standard mechanisms for the group selectors would introduce appreciable practical difficulties and would increase production costs. Moreover there would be difficulties in designing a selector which would hunt over 20 contacts in the short time available between successive digits.

The Strowger mechanism with 10 vertical steps and 10 effective rotary positions is, therefore, standardized for all switching stages and special circuit arrangements are introduced to increase the availability where necessary. In the standard 200-outlet group selector, the normal 10-level, 10-contact banks (actually there are 11 contacts on

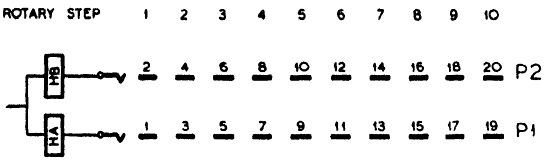


FIG. 49. ALLOCATION OF TRUNKS ON 200-OUTLET GROUP SELECTORS

each level but the last contact is not used as an outlet) are duplicated and the circuit is so arranged that 2 outlets are tested concurrently at each rotary step. The banks are arranged as 3 units, each unit having 2 contacts for each position of the wipers. The order of the bank contacts is as follows:

$P2$ —— } Upper Bank
$P1$ ——

-2 —— } Centre Bank
$+2$ ——

-1 —— } Lower Bank
$+1$ ——

The outlet to which the selector switches is determined by the conditions on the P-wire. Two switching relays are incorporated in the circuit, which is arranged so that both outlets on each rotary position are tested before hunting is allowed to continue to the next rotary position. It has been seen that one of the essential features of the Post Office system of grading is that the trunks of the grading shall be tested in a definite order. It follows that the circuit of a 200-outlet group selector must be designed so that if on any given step both outlets are free, then switching will take place to a specified outlet, i.e. when both outlets are free the choice should not be a matter of chance. Fig. 49 illustrates the allocation of the trunks of a grading to the bank contacts. The two switching relays HA and HB test the $P1$ and $P2$ banks respectively, and the circuit is arranged so that, if both outlets are free, the HA relay takes precedence and switches the call to the $P1$ bank. Thus, the first contact on the $P1$ bank is connected to the first trunk in the grading, the first contact of the $P2$ bank is connected to the second trunk, whilst the second contact of the $P1$ bank is the third trunk of the grading, and so on.

*It has been stated that an increase in the avail*ability increases the traffic capacity per trunk. This does not necessarily mean that it is more economical to provide group selectors with an availability of 20 since the economies which can be obtained by increasing the efficiency of the outgoing trunks must be weighed against the increased costs of providing group selectors with the increased availability. In Fig. 50 the number of trunks required for various volumes of traffic has been calculated for group selectors having availabilities of 10 and 20. Pure chance group traffic and a standard grade of service have been assumed. The full height (B) of each pillar gives the number of trunks required for selectors having an availability of 10, whilst the lower portion of each pillar (A) shows the number of trunks necessary when the availability is 20. The black portion (C) of each pillar does, therefore, represent the saving in the number of trunks required when the availability is increased from 10 to 20. In each case this

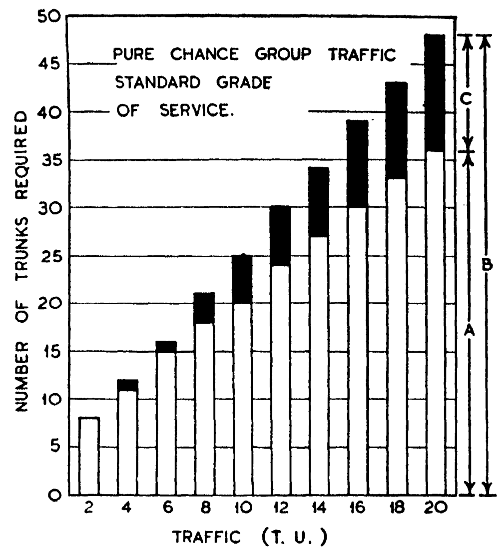


FIG. 50. SAVING IN TRUNKS OBTAINED BY THE USE OF 200-OUTLET GROUP SELECTORS

saving must be offset by the increased cost of the banks of each selector in the switching stage. Roughly speaking (and assuming that the selectors are reached from an earlier grading having an availability of 20), it is necessary to double the number of bank contacts on "A" selectors in order to obtain a saving of "C" trunks.

A saving in the number of trunks outgoing from a selector level produces a corresponding saving in

the number of selectors or junctions to which the trunks give access. As is to be expected, the balance in favour of 200-outlet selectors is greatest when the trunks from the selector level are connected to expensive external junctions. If the trunks give access to final selectors, the saving is not quite so great whilst, if the trunks are terminated by comparatively inexpensive group selectors, the saving is still further reduced. Fig. 51 shows the approximate economic limit to the use of 200-outlet selectors. The curves are based on estimates of the overall annual charges for both types of selector, and the percentage saving or loss on the 200-outlet switch is plotted against the volume of traffic per level. It will be noted that if the trunks are terminated by junctions of average length, it is more economical to utilize 200-outlet selectors if the traffic is in excess of approximately 4·75 T.U. per level (i.e. if the number of outgoing trunks required on a 200-outlet selector is in excess of 12). If the trunks are terminated by final selectors or by group selectors, then a 200-outlet selector is justified if the traffic exceeds 5·75 and 6·0 T.U. respectively (i.e. if the number of trunks required from a 200-outlet selector is in excess of about 14). If the traffic is less than the above figures, then the adoption of 200-outlet selectors cannot be justified on economic grounds. Even with very small values of traffic, however, the percentage loss due to the use of 200-outlet selectors is limited to a maximum of from 4 to 6 per cent. There are, moreover, considerable practical advantages in standardizing one type of group selector for all exchanges and for all switching stages, irrespective of the volume of traffic. It has therefore been decided that 200-outlet group selectors will be provided for all new exchange work.

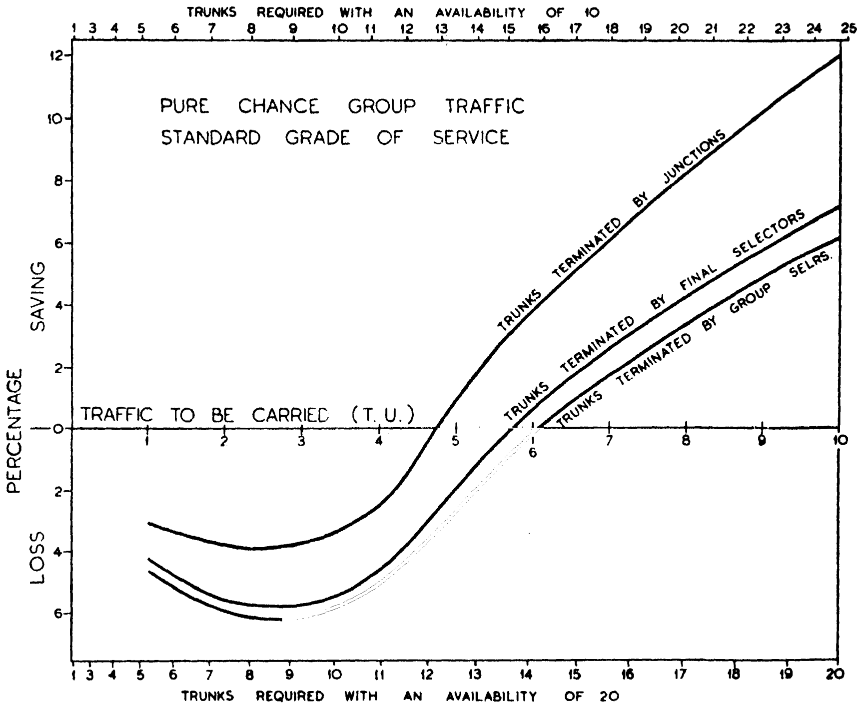


Fig. 51. Comparative Costs of 100-outlet and 200-outlet Group Selectors

The comparison in Fig. 50 of the relative efficiencies of 100- and 200-outlet group selectors is based on the assumption that the traffic is received from an earlier grading from which the traffic may be considered as "pure chance." The traffic on the levels of 1st selectors which are accessible from a large uniselector grading is, as has been seen earlier, somewhat more smooth. Under these circumstances the traffic capacity of the 100-outlet mechanism is increased to a greater extent than that of the 200-outlet selector. The saving is therefore correspondingly lower, but there is nevertheless almost always a very material economic advantage in the use of 200-outlet group selectors at the first switching stage owing to the comparatively high volume of traffic at this point.

The traffic carried on the various levels of a group selector may vary between wide limits, especially in the case of 1st selector levels. In practice, conditions often occur where the traffic on one or two levels is sufficiently great amply to justify the provision of 200-outlet selectors, but the traffic on the remaining levels may be small in comparison. With the Strowger mechanism it is not possible to vary the availability on the different levels of the selector, i.e. the availability of all levels must be either 10 or 20 irrespective of the volume of traffic to be carried on each level. It is considered by some authorities that this inflexibility is one of the limiting factors of the Strowger system.

200-line Final Selectors. The total traffic in an automatic exchange is divided into a large number of separate groups by the time it reaches the final selector stage. For example, in a 5000-line exchange, the total originating traffic may be quite appreciable, but this traffic is progressively divided at the 1st and 2nd group selector stages until it becomes 50 separate groups at the final selectors. In the majority of cases the volume of traffic to be carried by each final selector group is comparatively

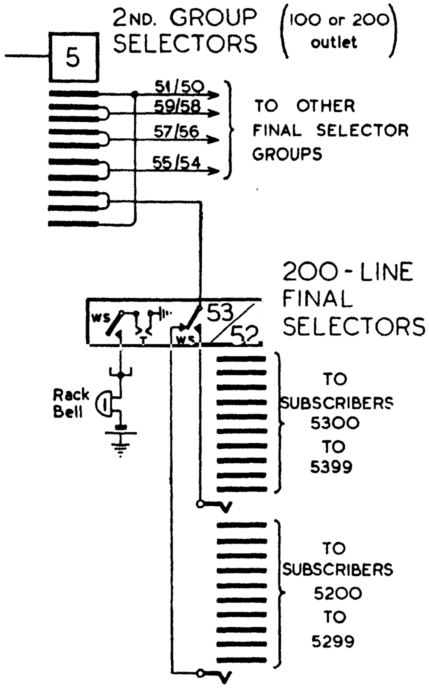


Fig. 52. Principle of 200-line Final Selectors

small, of the order of 2 to 4 T.U. per 100 lines. It has been seen that such small volumes of traffic require a comparatively small number of selectors and that such small groups of selectors are inefficiently worked. Some improvement in the economies of switch provision can be made by grouping the subscribers into units of 200 lines instead of the basic 100-line unit as provided for by the Strowger mechanism. The increased capacity cannot, of course, be obtained by increasing the number of levels or the number of contacts per level, since the positioning of the switch is determined by the final two digits of the subscriber's number. Final selectors are expensive mechanisms, primarily due to the large number of controlling relays required for automatic ringing, supervision, metering, transmission, etc. These controlling relays and the stepping mechanism itself are the same for all final selector groups, and it is readily possible to make a common group of final selectors serve two separate units of 100 lines each merely by the addition of a switching relay to divert the calls to one or other of two separate bank assemblies.

The principle of such 200-line final selectors is illustrated in Fig. 52. For purposes of illustration level 5 of 1st selectors is assumed. Levels 2 and 3 of the 2nd group selectors are cabled to a group of 200-line final selectors known as the 53/52 group. If the final selector is seized from level 2, a wiper switching relay (*WS*) in the final selector remains normal and the call is directed to the lower banks of the selector, i.e. to subscribers 5200 to 5299. If, on the other hand, a final selector is seized from level 3 of the 2nd group selector, the circuit is so arranged that relay *WS* in the final selector is operated and contacts of *WS* divert the call via the upper bank to subscribers 5300 to 5399. As in the case of the 200-outlet group selector, a ready means of determining the bank to which a call has switched is necessary for maintenance purposes. The short-circuiting of test springs on the final selector completes a circuit for the *test trunk bell* of the final selector rack should the *WS* relay be operated, i.e. if the call is switched to the upper or odd-numbered final selector group.

It is the usual practice, when 200-line final selectors are fitted, to group together levels 2–3, 4–5, 6–7, 8–9, and 1–0. The grouping of the 1st and 10th levels has certain cabling advantages in the wiring of the circuits from the final selector multiple to the M.D.F.

It is interesting to examine the economic limits of 100-line and 200-line final selectors. In Fig. 53 the number of 100-line final selectors required to carry various values of incoming traffic has been calculated. The number of 200-line final selectors to carry similar values of traffic has also been calculated and the respective numbers have been expressed as a ratio which is plotted against the volume of traffic per 100 subscribers. When the incoming traffic is low, say less than 1 T.U. per 100 lines, the number of 100-line final selectors required is between 1·4 and 1·6 times the number of 200-line final selectors necessary to carry the same traffic. In these circumstances there is a definite economic advantage if the total annual charges of 200-line final selectors are less than 1·4 to 1·6 times the similar charges for 100-line final selectors. When the incoming traffic is heavier, the ratio falls to between 1·25 and 1·35 but, even under these conditions, there is some slight advantage in the use of 200-line selectors if the cost of such switches is not greater than, say, 1·25 times the cost of a

100-line selector. This curve assumes that the final selectors are accessible from group selectors of the 200-outlet type. If 200-line final selectors were employed in conjunction with 100-outlet 2nd group selectors, then the economic advantage of 200-line final selectors is much reduced. This is shown by the broken line of Fig. 53, from which it is clear that 200-line final selectors are only economical for an incoming traffic of 3 T.U. (per 100 lines) if the cost is less than about 1·15 times that of a 100-outlet switch.

The Efficiency of Linefinders. The trunking problems so far considered in this chapter have assumed the use of subscribers' uniselectors to give access to the 1st group selectors of the exchange. Under these conditions the multiple from the uniselector banks can be dealt with either as a full availability group or, what is more usual, as a graded group. In an average exchange the uniselector gradings are normally very large, and a high standard of efficiency can be obtained in the trunking arrangements. In a linefinder scheme, on the other hand, the linefinders must of necessity

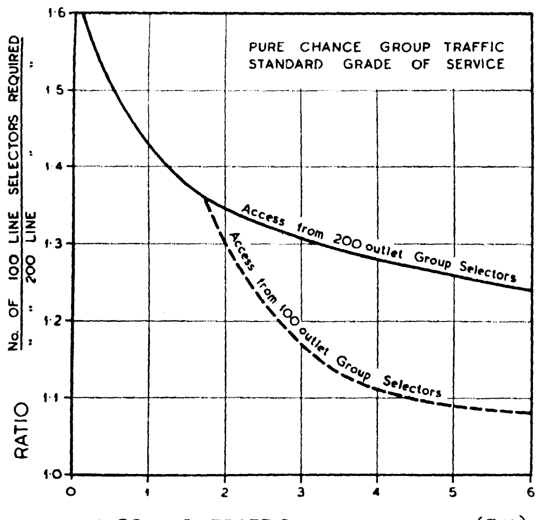


FIG. 53. COMPARISON OF THE NUMBER OF 100-LINE AND 200-LINE FINAL SELECTORS REQUIRED TO CARRY THE SAME VOLUME OF TRAFFIC

be subdivided into a number of separate and distinct groups, each group having access only to a limited number of lines which is determined by the capacity of the linefinder bank multiple. The start and allotter circuits are normally arranged so that any subscriber within a given linefinder group can be served by any one of the available finders in that group. Full availability conditions within the group therefore obtain. For various reasons, the bank capacity of a linefinder mechanism must be restricted to within reasonable limits (the time required to search for and seize a calling subscriber's line is an important factor in this connexion), and hence the total originated traffic of

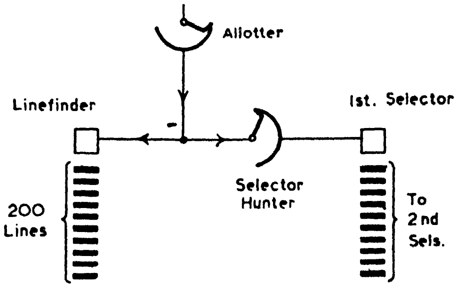


FIG. 54. LINEFINDER SCHEME WITH SELECTOR HUNTERS

the exchange is subdivided into a number o comparatively small full availability groups.

It has already been seen (Fig. 35) that the average traffic per trunk (in a full availability group) decreases very rapidly as the total traffic offered to the group is reduced. For example, a linefinder group with 10 switches will carry (for the standard grade of service) a total traffic of some 3·43 T.U., i.e. the average traffic per linefinder is only 0·343 T.U. These conditions are unavoidable unless linefinders with a larger bank capacity can be employed to increase the total volume of traffic within the group.

Use of Secondary Finders. With all the simple linefinder schemes described in Chapter I, a 1st group selector is directly connected to one particular linefinder. Under these conditions the inefficiency of the linefinder is reflected at the group selector stage, i.e. if the average traffic per linefinder is, say, 0·343 T.U., then the amount of traffic carried by each associated 1st selector is the same. Unlike the linefinders, the 1st selectors need not necessarily be subdivided into a number of separate groups. A considerable reduction in the number of 1st selectors required can be obtained by placing the 1st selectors in a common group and by providing a means of connecting a 1st selector to any linefinder as required.

One method would be to introduce *selector hunters* between the linefinders and the 1st selectors as shown in Fig. 54. With such an arrangement the trunks from the selector hunters could, if necessary, be graded to obtain the maximum efficiency. An alternative method is the use of *primary and secondary linefinders* as illustrated in Fig. 55. Both methods have been used, and a reasonable standard

of efficiency can be obtained by the use of secondary finder or selector hunter mechanisms of the uniselector type with 24 outlets. In general,

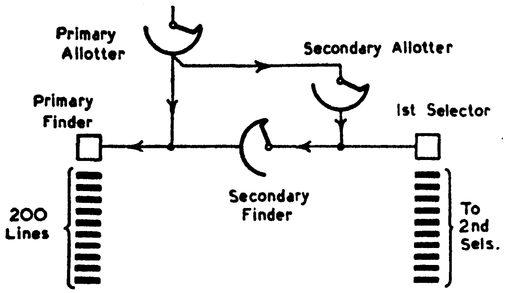


FIG. 55. LINEFINDER SCHEME WITH SECONDARY FINDERS

secondary finders are more economical than selector hunters for low calling rates, and, since subscribers' uniselectors are usually preferable to a cost of the secondary finders themselves and of their controlling circuits. We have seen that, in the case of a subscriber's uniselector where the trunks are always tested in the same order, the early choice trunks carry a high proportion of the traffic whilst (without grading) the later choices are very inefficiently worked (see Fig. 33). These conditions do not apply in a simple linefinder scheme, where the allotter distributes the traffic evenly to all the available linefinders in the group. If, however, it can be arranged that the allotter concentrates as much traffic as possible on a few selected linefinders, these linefinders can be connected direct to 1st selectors to obtain a high efficiency without the cost of secondary equipment. The remaining linefinders of the group can now be connected via secondary finders and the overall efficiency obtained is comparable with that of a full secondary scheme. This method is known as *partial secondary working*, and the linefinders in the first group are commonly known as *directly-con-*

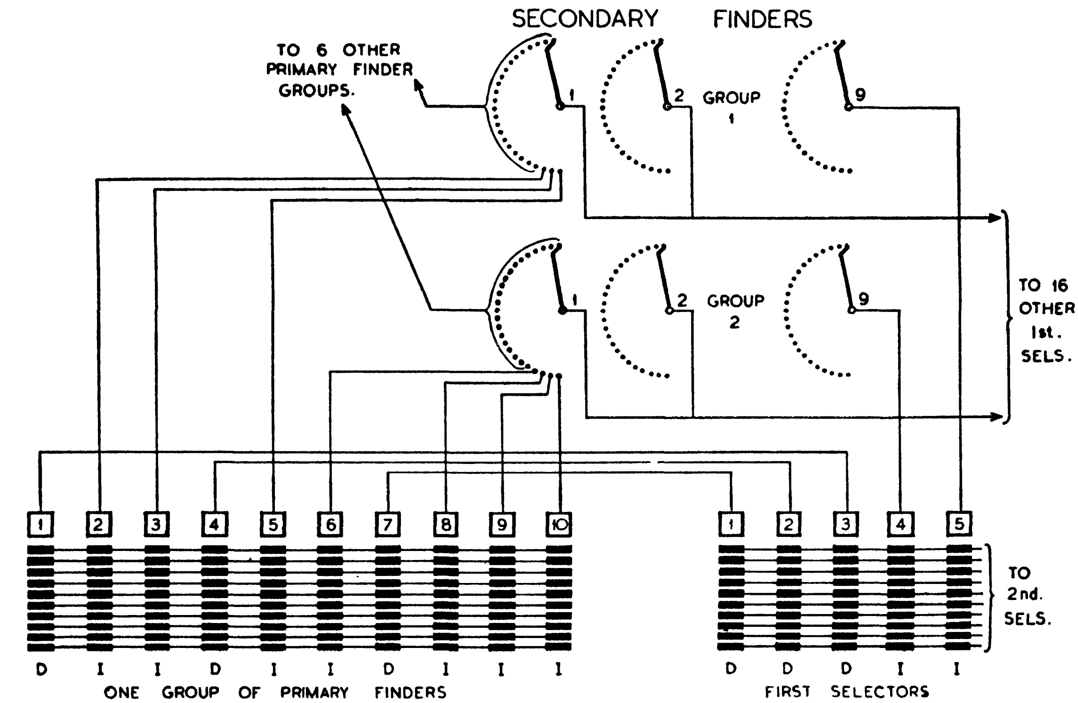


FIG. 56. PARTIAL SECONDARY LINEFINDER SCHEME

linefinder scheme when the calling rate is high, there is little scope in practice for a linefinder scheme with selector hunters.

Partial Secondary Working. The saving in the number of 1st selectors obtained by the use of secondary finders is offset to some extent by the *nected finders*, whilst those in the second group are referred to as *indirectly-connected finders*. With this scheme it is, of course, necessary to arrange for all the indirectly-connected finders to be busied out on the allotter banks until such time as all the directly-connected finders are engaged, i.e. the secondary

finders are only brought into service to carry the peak traffic of the group.

The general trunking principles of a partial secondary linefinder scheme are illustrated in Fig. 56. In order to smooth out the traffic routed via secondary finders, it is usual to trunk the indirectly-connected primary finders of any one group to as many secondary finder groups as possible. The number of directly-connected primary finders in any one group is usually from one-third to one-half of the total number of primary finders in the group; the number of indirectly-connected finders being a maximum when the calling rate is low. Fig. 57 gives some idea of the reduction in the number of 1st selectors resulting

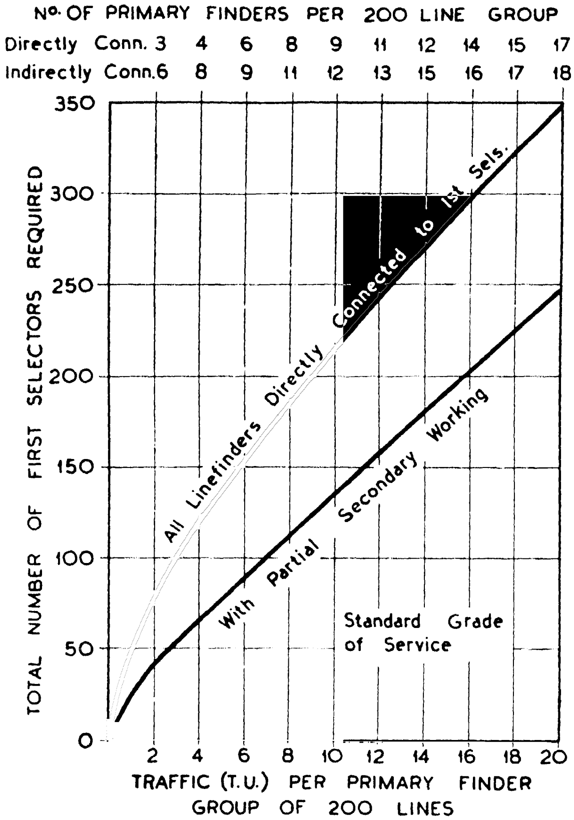


FIG. 57. FIRST SELECTORS REQUIRED IN A 2000-LINE EXCHANGE WITH AND WITHOUT PARTIAL SECONDARY WORKING

from the use of partial secondary working. The curves show the number of 1st selectors required for various values of originated traffic in a typical 2000-line exchange with and without partial secondary working. The curves are based on the standard grade of service and on the use of 200-point primary linefinders. The top of the illustration shows the number of primary finders required per 200-line group for various values of traffic, and also the

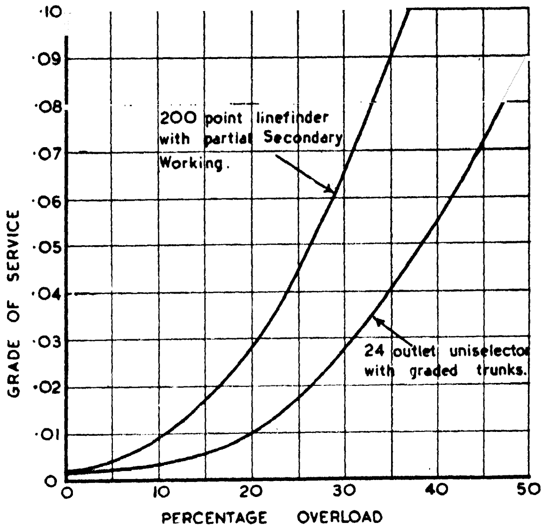


FIG. 58. COMPARISON OF LINEFINDERS AND UNISELECTORS WITH OVERLOAD CONDITIONS

proportion of these finders which are directly and indirectly connected.

Although the partial secondary linefinder scheme is more efficient than subscribers' uniselectors (and, incidentally, has a lower initial cost than uniselectors except for the higher calling rates), experience has proved that there are a number of difficulties which make linefinders less attractive than was at first envisaged. In the first place, a modern linefinder scheme (due to its high traffic efficiency) is more liable to degrade the service during periods of abnormally heavy traffic. Fig. 58 shows the degradation in the grade of service with various degrees of overload. The superiority of the uniselector at very heavy overloads is clearly indicated. The partial secondary linefinder scheme is also much more complex than the uniselector, and the maintenance costs have proved to be rather high. The linefinder scheme is also somewhat less flexible than uniselectors. If, for any reason, the calling rate at a uniselector exchange increases beyond the expected figure, it is readily possible to cater for this increase in traffic by regrading the uniselector outlets. In the linefinder scheme, however, it is difficult to extend the linefinder bank multiple, and it is sometimes necessary to restrict the number of lines connected to each group in order that the linefinder bank capacity shall not be overloaded.

Recent cost comparisons, which take all these factors into consideration, have indicated that, generally speaking, uniselectors are more economical when the calling rate is greater than 0·4 (see Fig. 59). Well over 90 per cent of the total lines in Great Britain have a calling rate in excess of this figure, and hence it has been decided that all future exchanges, except small rural units, shall be equipped with subscribers' uniselectors. It is possible that future improvements in the linefinder mechanism and circuit may justify a reversion to the linefinder principle for medium size and large exchanges, but in the meantime preference is being given to the simpler and more flexible uniselector.

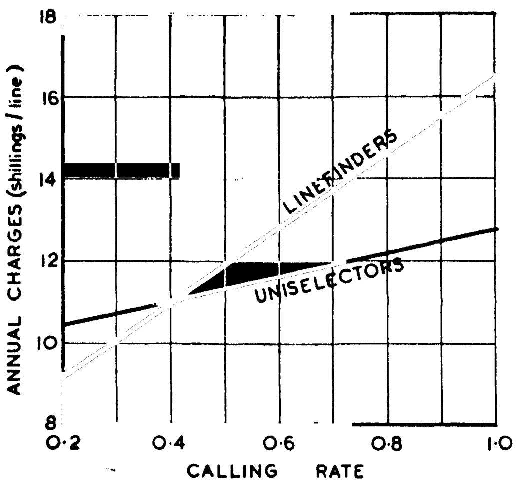


FIG. 59. RELATIVE COSTS OF UNISELECTORS AND LINEFINDERS FOR VARIOUS VALUES OF CALLING RATE

Traffic Meters. Facilities are provided in every automatic exchange to maintain a continual watch on the adequacy or otherwise of the switching plant. The primary source of information comes from *traffic meters* and *call counting meters* which are provided at all the important switching stages to record congestion and overflow conditions. In general, traffic meters are provided as follows:

Late-choice Call Meters (*L.C.C.M.*). One meter of this type is usually connected to the last contact of each uniselector grading to record the number of times that particular choice is seized. Late-choice Call Meters are also used in other circumstances where continuous hunting uniselectors are employed (e.g. the A-digit selector hunters, etc.).

Late-choice Traffic Unit Meters (*L.C.U.M.*). Late-choice Traffic Unit Meters are associated with the Late-choice Call Meters and record the cumulative time (in half-minutes) that the trunk is in use. The L.C.U.M. readings for 1 hour when divided by 120 give the total traffic (in T.U.s) carried by the late-choice trunk. Moreover, the ratio between the reading of the L.C.U.M. and the reading of the L.C.C.M. gives the average duration of the calls expressed in half-minutes.

Group Occupancy Meters (*G.O.M.*). These meters are fitted to certain types of full availability groups and record the number of occasions when all circuits in the group are simultaneously engaged.

Group Occupancy Time Meters (*G.O.T.M.*). This type of meter is used on full availability groups and is connected so as to record the cumulative time (usually at 1 second or 2 second intervals) that all outlets in the group are engaged.

Overflow Meters (*O.M.*). Overflow Meters are connected to the 11th step contacts of 2-motion selectors to indicate the number of calls which fail to obtain a trunk in that particular grading. They are used on the levels of most group and similar selectors. It is interesting to note that an overflow meter will not record a second overflow whilst the meter is being held by any subscriber. Busy Tone is returned to the caller when a switch steps to the 11th rotary position, but it is found that there is usually a delay of from 10 to 15 seconds before the subscriber replaces his receiver. Should another call fail to find a trunk during this period, there will be no record on the overflow meter. The overflow reading is reasonably accurate when the number of overflows is small, but the greater the number of overflows, the greater is the chance of false readings.

Call Counting Meters (*C.C.M.*). Call Counting Meters are connected to the release circuit of certain pieces of apparatus, such as directors, to record the total number of times when this particular piece of apparatus is taken into use.

In addition to the above, traffic meters are also fitted in special circumstances such as, for example, to record the amount of traffic being passed over a specific route or handled by a certain manual board position.

It is usual to read traffic meters at the beginning and end of a one-and-a-half hour period which includes the busy hour, a correction being made to scale down the readings to the busy hour figures. At a new exchange, daily readings are taken for the first month, but after that the traffic meters are read at monthly intervals. The traffic meter readings are then compared with standard tabulations which indicate the *critical meter readings* for the minimum permissible grade of service. Thus, if the readings obtained are greater than the critical figure, it is an indication that the grade of service is below standard. The tabulations for

overflow readings usually give the critical figure as a factor which, when divided by the average holding time, gives the critical number of overflows which can be compared with the actual meter readings.

Traffic Records. In addition to the information obtained from the traffic meters, it is usual to arrange for a complete record of the traffic in an automatic exchange once every six months. We have seen in previous paragraphs that the number of simultaneous conversations is a measure of the traffic flow in T.U.s. It is usually possible to determine the traffic at any switching stage or in any group of junctions, etc., by ascertaining the average number of simultaneous connexions during the busy hour. One method is to arrange for visual observation, at regular intervals throughout the busy period, of the number of switches, etc., engaged. Usually a count is made every three minutes for three consecutive half-hours which are known to include the busy hour. The tests are repeated on three successive days, and from these results the time of the busy hour and the average traffic at each stage can be calculated.

Manual "switch counts" are laborious and there is sometimes difficulty in obtaining the necessary staff without the disorganization of other work. Moreover, it is important, for accurate results, that each switch be examined at regular intervals—a condition not easily obtained in a manual switch count. Automatic *traffic recorders* are now fitted as the standard equipment in all large telephone exchanges, and replace the previous manual methods. The traffic recorder utilizes uniselectors to test the P-wires of the selectors and to count the engaged switches on a series of recording meters. Usually the test is repeated every 30 seconds, and hence gives a more accurate record of the traffic flow than any manual method. Details of the traffic recorder are given in a later chapter of this volume.

EXERCISES II

1. (*a*) Explain what is meant by a "unit call" and indicate how the traffic load to an operator is determined by means of this unit.

(*b*) What is meant by the term "calling rate"? State precisely how the calling rate is related to the number of operators' positions required in a manual exchange, and to the switching equipment in an automatic exchange. (*C. & G. Telephone Exchange Systems II*, 1947.)

2. State the meanings given to the term "traffic unit" as used in automatic telephony. Observation of a full availability group of selectors, during the busy hour, showed that the average number of calls in progress simultaneously was 10, and that all the selectors were in use simultaneously for a total period of 7 seconds. Calculate the traffic, in traffic units, offered to the group during the busy hour. (*C. & G. Telephony, Grade II*, 1943.)

3. Define the terms "full availability" and "grade of service" as used in connexion with the routing of traffic at automatic exchanges.

Calculate (*a*) the grade of service when two traffic units are offered during the busy hour to a full availability group of three trunks, which are always tested in the same order, and (*b*) the traffic carried by the first-choice trunk.

Traffic lost may be taken as:

$$\frac{A \cdot \dfrac{A^N}{N!}}{1 + A + \dfrac{A^2}{2!} + \cdots + \dfrac{A^N}{N!}}$$

where A is the traffic offered during the busy hour and N is the number of trunks. (*C. & G. Telephony, Grade II*, 1945.)

4. What are the advantages and disadvantages of connecting automatic selectors by grading instead of by direct cabling from bank outlets to subsequent selectors? Use for illustration a diagram of a grading from 4 groups of 100-outlet selectors. (*C. & G. Telephony, Grade I*, 1945.)

5. Mark on a schematic diagram the points at which the trunks between ranks of switches would normally be graded in the case of a 4-digit automatic exchange in which subscribers' uniselectors are used.

Give a diagram of a 6-group grading of 27 trunks, the availability being 10. (*C. & G. Telephone Exchange Systems I*, 1948.)

6. Describe, with the aid of a schematic diagram, the trunking features of the partial secondary line-finder system employed for connecting subscribers' lines to 1st selectors. (*C. & G. Telephony, Grade II*, 1938.)

7. Derive the smoothest 10-group grading for 47 trunks and an availability of 10, and show by a mathematical sketch that the design selected is smoother than any two alternative arrangements. (*C. & G. Telephony, Grade II*, 1946.)

8. Show that the number of traffic units carried by the last-choice trunk of a full availability group of N trunks, which are always tested in the same order, is given by $B(N - A)$, approximately, where A is the traffic offered to the group, and B, the grade of service, is good. When a full availability group

of 17 trunks is offered 7·95 traffic units during the busy hour, the grade of service given is 0·002. If the same traffic load were offered during eight successive busy hours, and the average duration of the calls was 2·9 minutes, what reading would be obtained on a congestion meter associated with the last-choice trunk in the group during the eight busy hours? (*C. & G. Telephony, Grade III*, 1945.)

9. In a certain 4-group grading for 7 trunks, each group has an individual trunk as the first choice, followed by 3 trunks which are common to all groups. Calculate the traffic carried by each trunk when a total of 2·0 traffic units is offered to the grading during one hour. It should be assumed that:

(i) Calls arrive in pure chance order.

(ii) Traffic is evenly distributed over the four groups.

(iii) The traffic carried by the 2nd, 3rd and 4th choice trunks of the grading is equal to that carried by the corresponding choices in a full availability group of 4 trunks in which the traffic offered to the 2nd choice trunk is the same as in the grading. (*C. & G. Telephony, Grade III*, 1946.)

10. The proportion of local calls in a telephone system having a holding time greater than t may be said to be $\varepsilon^{-\frac{t}{h}}$ where h is the *average* holding time of the calls.

Normally, in automatic exchanges, local calls are metered once only when the called subscriber answers. Calculate the proportional increase in revenue likely to be obtained if the calls were metered again at the end of each successive 3-minute interval, assuming that the *average* duration of the calls were (a) 2·0 minutes, and (b) 3·0 minutes. (*C. & G. Telephone Exchange Systems III*, 1948.)

CHAPTER III

AUTOMATIC SWITCHING MECHANISMS

Most automatic telephone systems are based upon some form of electromechanical device for the process of selection. These mechanisms (known generally as *selectors*) are the key components of every automatic telephone exchange, and the satisfactory performance of the whole system depends upon their reliability and efficiency.

The successful design of any automatic selector depends primarily on the experience that the designer has in the use of a variety of ferrous and non-ferrous materials. Choosing the right amount of the best material is one of the main problems. After the selection of the material, the detailed design of the piece parts must be such that no unsurmountable difficulties are presented to the jig and tool designers, or to the people concerned with the mass production of the parts. Finally, the design must be such that all the piece parts fit together into a structure which provides the desired operational characteristics.

The design of automatic telephone switches—in common with other pieces of animate mechanism—is a highly specialized art. The designer must have some knowledge of all the known methods of fabricating metallic and insulating materials. He gains this knowledge firstly by experience, and secondly by consultation with people skilled in the various specialized branches. The shape of the whole item so designed is largely a matter of the designer's imagination in grasping the essential requirements of the item, the space in which it fits, and how exacting is each and every function which the item or mechanism is expected to perform.

It is not possible with the space available in this chapter to examine all the theoretical and practical aspects of selector design, but some of the more important principles are considered in the following paragraphs.

Electromagnet-operated Stepping Actions. We have seen that the Strowger system of automatic telephony is essentially a step-by-step system, i.e. the wipers are positioned "step-by-step" in response to consecutive impulses from the subscriber's dial. Apart from this "dial controlled" stepping, the selectors are also required to search over selected groups of contacts to find a free trunk to the next switching stage. Selectors have therefore two distinct functions.

The length of individual impulses and the frequency at which impulses are transmitted by a subscriber's dial may vary within certain limits, and hence it is not possible to utilize any form of time control for the positioning of the selectors. If step-by-step selection is required, then the only practicable solution is to design a selector which will make one step in the process of selection for each impulse received—irrespective of the length and frequency of the impulses.

The requirements may be met by the use of electromagnets which can be energized by each successive impulse. The energization of the electromagnet can be made to operate an iron armature which is mechanically coupled to the mechanism so that the selecting wipers move one step forward for each energization of the electromagnet. Usually this mechanical coupling is in the form of a ratchet and pawl system. There are two alternative arrangements:

(*a*) Forward-acting selectors where the wipers are moved during the *operation* of the electromagnet armature.

(*b*) Reverse-acting switches where the attraction of the electromagnet armature tensions a restoring spring and, on the *release* of the armature, the restoring spring moves the wiper assembly.

The relative merits of these two main methods of control are considered later.

Fig. 60 shows the fundamental arrangements of a *forward-acting* selecting mechanism. The circuit is arranged so that each break impulse from the subscriber's dial energizes the electromagnet once. The armature of the electromagnet is pivoted at one end and carries a suitable *pawl* at the other end. This pawl engages with a *ratchet wheel* rigidly attached to the *wiper assembly* so that each energization of the electromagnet causes the pawl to move the ratchet wheel one step forward. A *detent* is required to hold the ratchet wheel and the wiper assembly in position after each consecutive step. At the end of each impulse, the armature is returned to normal by the action of the *armature restoring spring*. Springs are also required on the pawl and detent to ensure that they engage properly with the teeth of the ratchet wheel.

Fig. 61 shows an alternative mechanical arrangement based on the principle of *reverse action*. In this case the pawl is designed to slip over the long face of the ratchet tooth during the operation of the electromagnet armature, but to engage with the ratchet and to move round the wiper assembly

on the *release stroke* of the armature. Whereas in Fig. 60 the electromagnet provides the tractive force for the movement of the wiper assembly, the arrangements shown in Fig. 61 rely upon the tensioned armature restoring spring for imparting movement to the ratchet wheel, etc. As in the previous case, a detent is required to hold the ratchet wheel and the wiper assembly in position between each step. The detent and also the pawl must be provided with springs to ensure proper engagement with the teeth of the ratchet wheel.

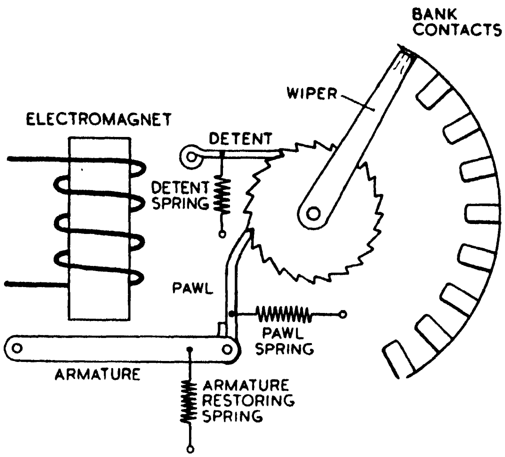


FIG. 60. FORWARD-ACTING RATCHET AND PAWL DRIVE

Although the use of an electromagnet with an associated ratchet and pawl system is almost essential in a selector which must move step by step under the control of dial impulses, there is no fundamental reason why the automatic hunting action of selectors should not make use of some alternative form of drive. It would, for example, be quite possible to design a step-by-step selector with electromagnetic control of those movements directed by dial impulses, but to provide, say, a motor drive for the automatic hunting action. In practice it is generally undesirable to have two different forms of drive in the one selector, and hence it is usual for step-by-step selectors to utilize ratchet and pawl drive both for the automatic hunting action and for the dial controlled movements. This permits the use of standard mechanisms which can be used as required for automatic or dial controlled movement.

Unidirectional and 2-motion Selectors. The main switching mechanism of the British system is a 2-motion selector, the bank contacts of which are arranged as 10 rows, each of 10 contacts. Electromagnets, in conjunction with suitable ratchet and pawl systems, enable the wipers to be stepped, first to the required level and then to the desired rotary position in that level. These 2-motion selectors are invariably of the forward-acting type, i.e. the wipers are moved during the attraction of the electromagnet armature. Once positioned, the wipers are retained by means of a system of detents, which engage with the ratchets for the duration of the call. On mechanisms of the pre-2000 type, release is effected by the operation of a *release magnet* which withdraws the detents from the ratchets. The wipers are now free to rotate backwards over the level under the action of a coiled spring, and then to drop vertically to the normal position by the force of gravity. In selectors of the later (2000) type, the release action consists of the re-establishment of the rotary stepping circuit and, when the wiper carriage is moved to the 12th rotary position, it restores first vertically and then horizontally under the action of a coiled spring. The basic movements of the two types of selector have already been considered in Chapter I.

Apart from the 2-motion selector, unidirectional selecting mechanisms (*uniselectors*) are required as a means of connecting the subscriber's line to the 1st selector and for various miscellaneous purposes. A 25-point uniselector has been found to be the most convenient size, and the standard mechanism is of this capacity. It can provide either 25 working outlets, or, alternatively, 24 outlets plus a "home" position. Modern practice favours the reverse-acting principle for uniselectors in view of the more satisfactory performance under self-driving conditions (see Chapter VII).

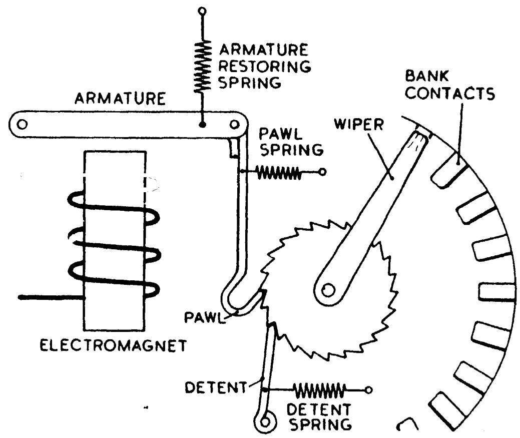


FIG. 61. REVERSE-ACTING RATCHET AND PAWL DRIVE

A motor-driven high-speed uniselector with a 51-point bank and up to 16 wipers has recently been adopted as standard for certain special purposes (e.g. for searching over large groups of

outgoing trunk lines). The wipers of this mechanism are rotated via a train of gears from a miniature electric motor individual to the switch. A very high speed of search is obtainable by means of this switch, and a special latch system is incorporated to arrest the motion of the wipers when the desired contact has been reached.

Die-castings. In recent years increasing use has been made of pressure die-casting technique for the production of non-ferrous piece parts for automatic telephone equipment. The production of large numbers of intricate piece parts by this method has considerably eased and cheapened the supply position, whilst at the same time it has relieved the pressure of work on the machine shops. Two classes of alloys have proved particularly suitable for telephone work—those having zinc as their base, and those using aluminium.

Zinc Base Die-castings. This class of alloy has a high tensile strength (16–18 tons/sq in.), a good resistance to corrosion, and casts well. The alloys generally in use are manufactured from high-purity zinc to specification B.S. 1003 with alloying elements to composition B.S. 1004. The alloy is easy on the dies, and up to 100 000 castings of good dimensional accuracy can often be obtained without retouching from one set of dies. Dimensional stability has to be carefully watched and the maximum impurity limits quoted in the relevant specification (particularly lead, tin and cadmium) must be strictly maintained. Zinc base castings are considerably heavier than the aluminium base alloys, and where weight is of major importance the lighter class of alloys would normally be utilized. A typical example of a zinc base die-casting is the antibounce plate which is now fitted to the bottom bridge piece of a 2000 type selector (q.v.).

Aluminium Base Die-castings. There are many varieties of aluminium base alloys for die-casting purposes. The type most commonly used in the telephone industry is the aluminium-silicon series (silicon 10 per cent nominal) and known as L 33, D.T.D. 424, or S.T.A. 7/A.C. 2. The silicon group of alloys has come into prominence mainly by reason of their high fluidity, good mechanical properties, freedom from hot-tearing and a high resistance to corrosion. Among the difficulties the engineer has to contend with are poor machining qualities and a tendency to porosity behind heavy sections. The frame of the 2000 type selector is a very good example of an aluminium-silicon die-casting.

All die-castings are subjected to a searching visual examination and suitable physical tests to ensure that each component will be reliable in service. Radiographic examinations are regularly undertaken to ascertain the locality and magnitude of any porosity in the castings. When this examination indicates excessive air locks, the consignment is rejected. Control of the chemical composition is also important and spectrographic analysis is used to give rapid and accurate results. Further, there is a visual examination for neatness of fettling, freedom from cracks, shrinkage depressions, cold shuts, heat-checks, and other surface defects. For zinc base die-castings a special steam-ageing test is used to ascertain any tendency to inter-crystalline cracking and dimensional alterations. These dimensional changes are mainly due to excessive amounts of impurities, such as cadmium, lead and tin. The samples are immersed in steam for some ten days, and after this treatment each sample is measured for growth and is tested to ascertain if there is any change in mechanical properties.

Steel Pressings. Many of the piece parts of automatic selectors are steel pressings. The steel sheets used for this purpose must have a good ductility and are particularly selected for surface finish, dimensional accuracy and chemical composition. The completed parts must have a surface capable of taking a protective enamel or an electro-deposited coating without showing any signs of base imperfections. They must be strong enough to withstand the stresses applied during service, and must also be capable of taking heavy drawing operations during manufacture. There are some 100 British Standards for sheet steel, but the very rigid requirements of the telephone industry have necessitated the preparation of independent Specifications for the sheet steel used for deep drawing.

The manufacturing process of each particular piece part does, of course, depend upon the shape, complexity and the individual requirements of that part. The operations most commonly used in the production shops are *blanking*, *piercing*, *bending*, *forming* and *drawing* (either deep or shallow), and *upsetting*. The quality of the steel sheet selected for any part depends upon a number of factors. In every case it is necessary to consider:

Surface Finish. The sheets must possess clean, bright surfaces, free from any physical imperfection such as rust, dirt, scale, pitting, seams, score marks, and so on. Suitable sheet can generally be obtained by the purchase of what is known in the trade as C.R.C.A. (cold, rolled, close, annealed) sheets or, for the best type of work, cold, rolled, bright mild steel sheet.

Dimensional Tolerances. Automatic selectors are precision mechanisms, and the tolerances on the materials used must be strictly maintained. Typical

tolerances allowed on deep drawing steel sheets are:

Material up to and including 0·02 in. .	± 0·0015 in.
From 0·02 in. up to and including 0·04 in. .	± 0·002 in.
From 0·04 in. up to and including 0·08 in. .	± 0·003 in.

Material which is not uniform in cross-section or which is outside the tolerances quoted would cause considerable difficulties with the press tools, and would result in an excessive number of rejections at the inspection stage.

Chemical Composition. The chemical composition of the steel is of fundamental importance. In this connexion it should be borne in mind that in a number of cases the deep drawing properties of the steel have to be coupled with certain magnetic requirements. Thus, the material used for a relay core or yoke must have a low coercive force to meet the magnetic requirements, but must at the same time have the necessary mechanical characteristics to permit the material to be "cold headed." These dual requirements often necessitate a compromise in composition. Generally speaking, a soft mild steel with the minimum amounts of metallic impurities (such as Armco or Swedish iron) will give the optimum magnetic characteristics, whilst steels having higher manganese and slightly wider tolerances on the carbon content have better drawing properties. The following are typical specifications for three classes of sheet steel and strip.

Type 1. *Good Magnetic Quality.*

Carbon . .	. Less than 0·05 per cent
Silicon . .	. Less than 0·05 per cent
Sulphur .	. Less than 0·02 per cent
Phosphorus .	. Less than 0·02 per cent
Manganese .	. Less than 0·15 per cent
Other Impurities	. Nil
Iron . .	. Remainder

Type 2. *Deep Drawing and Good Magnetic Properties.*

Carbon . .	. Less than 0·10 per cent
Silicon . .	. Less than 0·02 per cent
Sulphur .	. Less than 0·04 per cent
Phosphorus .	. Less than 0·04 per cent
Manganese .	. Less than 0·30 per cent
Other Impurities	. Nil
Iron . .	. Remainder

Type 3. *Deep Drawing Properties and Moderate Magnetic Qualities.*

Carbon . .	. 0·05–0·15 per cent
Silicon . .	. Less than 0·30 per cent
Sulphur .	. Less than 0·05 per cent
Phosphorus .	. Less than 0·05 per cent
Manganese .	. 0·30–0·60 per cent
Other Impurities	. Nil
Iron . .	. Remainder

Physical Properties. The amount of cold work which can be carried out on any particular material can be ascertained in advance by an examination of its physical properties. In practice all raw material which has to undergo drawing operations during manufacture is tested prior to its delivery to the press shops. The tests most likely to indicate the suitability of the material are:

(*a*) *Erichsen Draw Test.* This simulates (as far as possible) the conditions likely to be met with in practice, and consists of forcing a steel ball of known diameter into the sheet under test. By measurement of the depth of impression prior to cracking, and by inspecting the outer edge of the cup formed (for grain size and orange peel effect), a good indication is obtained on its deep drawing properties. Typical figures for a deep drawing steel of Type 2 are:

Thickness (*in.*)	*Minimum Erichsen Draw* (*mm*)
0·018	8·7
0·022	9·2
0·028	9·9
0·036	10·3
0·048	10·9
0·064	11·7
0·080	12·5

(*b*) *Hardness.* Generally speaking, the softer the material the better it will draw. Special heat treatment by the makers (such as spherodizing) considerably improves the deep drawing properties with very little effect on the hardness values. Strip material, on the other hand, has to be used in the "quarter hard" condition when wanted for cold heading, since the dead soft variety produces kinks and bends too easily. The hardness testing can be carried out on Vickers' hardness testing machines, which measure (by means of a microscope) the impression left by a diamond which has been forced by a known load into the polished surface.

(*c*) *Bend Tests.* The material should withstand a close bend test of 180° (i.e. flat on itself), each way of the grain without showing the slightest visible signs of fracture or the development of cracks. The direction of the grain can play an important part in the ability of a steel sheet to take a forming operation. Any rolled section, whether sheet or strip, has a grain running along it in the direction of rolling. This grain is not always visible to the eye, particularly in deep drawing material where the surface effects of cold working may be mostly removed by the annealing processes. It is always more difficult to bend steel in a direction parallel to the grain than in a direction at right angles to the grain since the first signs of cracking are always more easily produced along the grain. In this

connexion steel behaves very much in the same way as wood.

Heat Treatment. Annealing or normalizing treatments can be used after the sheet steel has been subjected to the maximum amount of cold work which can be applied before there are signs of cracking. These treatments have the effect of relieving the strains put on the crystals during the cold work, and when carried out above the recrystallizing temperature, completely reform the crystal shape and size. This allows for further cold work in the shape of drawing or bending without the danger of fracture.

Deep Drawing Brasses. Before leaving the subject of deep drawing, it is perhaps advisable to mention the more important properties of copper alloys required for piece parts which are subjected to deep drawing during manufacture. The quality of the surface finish is more important than with sheet steel. The high surface finish which cold rolling produces imparts a protective skin to the metal, which considerably improves its resistance to corrosion. One disadvantage of this highly finished skin is, however, that it may mask surface imperfections which may appear only after some cleaning or pickling operation during manufacture. Samples of sheet brass are therefore often submitted to an acid dipping test to ensure that these surface imperfections are not likely to develop during production.

The brasses used for deep drawing are usually of the "cartridge" type, with a nominal composition of 70 per cent copper, 30 per cent zinc. These brasses are commonly known as alpha brasses, and the copper content can fall as low as 63 per cent. At normal temperatures copper can hold in "solution" something like 37 per cent zinc, and the resultant alloy forms uniform crystals known as *alpha brass*. This homogenous mixture is admirable for deep drawing operations, but if the zinc content rises above 37 per cent a brittle second constituent, known as *beta brass*, begins to form, and the cold working properties immediately begin to fall off. Impurities will, of course, also cause trouble during drawing operations, and these (as in the case of steel) must be kept down to the absolute minimum.

The effects of cold working on alpha brasses can be removed by suitable annealing (generally at about 600°C). This annealing process can be repeated up to four or five times—if necessary after each cold draw. All brasses intended for deep drawing are purchased in the annealed condition, and have a maximum specified hardness of 75 D.P.N. Various other tempers can also be used, such as quarter hard, half hard, and so on, according to the amount of cold work which is to be applied.

One serious difficulty encountered with deep drawing brasses is the phenomenon known as "season-cracking." Often brass piece parts are found which have cracked after being placed into service or even in store. The actual cracking is caused by small traces of ammonia, moisture, and oxygen in the atmosphere, which produce intercrystalline cracks on cold worked alpha brasses. Season-cracking can usually be prevented by low temperature annealing, which relieves the stress on the strained crystals. The normal treatment would be to subject the part to a temperature of from 250°C to 300°C for $\frac{1}{2}$ hour to $\frac{3}{4}$ hour.

Helical Restoring Springs. Helical extension and compression springs are used to a considerable extent on mechanisms of the step-by-step type to

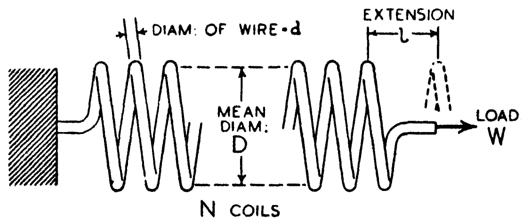


FIG. 62. HELICAL RESTORING SPRING

provide the necessary restoring force on electromagnet armatures. The material of such springs is primarily subject to a torsional stress, and the force which any given spring will provide is determined by certain mathematical laws, i.e.:

(*a*) The stiffness of the spring varies as the fourth power of the diameter of the wire.

(*b*) The stiffness varies inversely as the cube of the mean diameter of the helix.

(*c*) The strength of the spring per unit of extension (or compression) varies inversely as the number of active coils in the spring.

The build-up of tension of a helical spring constructed of round wire (Fig. 62) can be calculated from the following formula:

Load required per inch of extension

$$= \frac{W}{l} = \frac{Gd^4}{8ND^3} \quad . \quad . \quad . \quad (1)$$

where W = load (lb),

l = extension (in.),

d = diameter of the wire (in.),

N = number of active coils,

D = mean diameter of helix (in.),

G = modulus of rigidity (lb per sq in.).

The modulus of rigidity (sometimes known as the modulus of transverse elasticity) does, of course, depend upon the material of the spring, the heat

treatment, etc. The following list gives typical values of common materials:

Material	Modulus of Rigidity (G) (lb/sq in.)
Carbon Steel Wire . .	$11{\cdot}5 \times 10^6$
Staybrite (Stainless Steel) .	$9{\cdot}15 \times 10^6$
Chrome Vanadium . .	$11{\cdot}5 \times 10^6$
Phosphor Bronze . .	$6{\cdot}25 \times 10^6$
Nickel Silver . . .	$5{\cdot}5 \times 10^6$

The stress in the material for a spring made of round wire is given by:

$$S = \frac{8WD}{\pi d^3} \quad . \quad . \quad . \quad (2)$$

where S = sheer stress (lb/sq in.),
W = load (lb),
d = diameter of wire (in.),
D = mean diameter of coil (in.).

In practice, some springs are adjusted to have an initial tension, i.e. the material of the spring is under torsional stress before elongation takes place. The initial stress in the material (S) can be calculated from the above formula, if the physical dimensions of the spring and the initial tension (W) in the material are known.

The stress in the material of a spring must not at any time exceed the elastic limit for the particular material (the limit of stress within which the resulting strain completely disappears after the removal of the load). The elastic limit for a steel spring is of the order of 20 000 lb/sq in. but the value varies over a wide range depending upon the heat treatment, etc.

The above formulae are strictly accurate only where the material is straight. In a helical spring the material is in coiled form and the curvature of the wire must theoretically be taken into account. This curvature imposes a higher stress on the inside diameter of the coil, and for detailed calculations a correction factor must be used.

In the design of automatic switching mechanisms it is necessary to consider the effects, not only of slowly applied loads, but also when the load is applied suddenly to the spring by moving parts which have appreciable kinetic energy. The calculations are somewhat complex due to the fact that the velocity at which the load is applied is not readily obtainable. A rough approximation can be obtained by considering the work done on the spring (i.e. the force multiplied by the distance moved) and equating this to the work done by the spring. It can be shown that, if the load is applied suddenly, the deflection is approximately double that which would occur if the same load were applied slowly, i.e.:

For suddenly applied loads:

$$\text{Extension} = l = \frac{16WND^3}{Gd^4} \text{ approx.} \quad . \quad . \quad (3)$$

EXAMPLE. The armature of a reverse-acting uniselector is restored by two helical springs of identical construction. Each spring has 25 complete turns of 0·025 in. diameter steel wire wound into a helix of 0·3 in. mean diameter. The modulus of rigidity of the steel is 10×10^6 lb/sq in. and the sheer stress must not exceed 20 000 lb/sq in. It may be assumed that there is no initial tension in the springs.

Calculate:

(*a*) The force exerted by each spring when it is extended 0·25 in. by the operation of the armature.

(*b*) The force provided by each spring (when extended) if 2 turns are made ineffective by means of an adjusting screw.

(*c*) The maximum permissible extension of the spring when the full number of turns are effective.

From Equation (1),

$$W = \frac{lGd^4}{8ND^3}$$

Substituting,

$$W = \frac{0{\cdot}25 \times 10 \times 10^6 \times 0{\cdot}025^4}{8 \times 25 \times 0{\cdot}3^3}$$

or $$\text{force} = W = 0{\cdot}1808 \text{ lb} \quad . \quad . \quad (a)$$

The force is inversely proportional to the number of effective turns. Hence, when 2 turns are made ineffective:

$$\text{force} = \frac{25}{23} \times 0{\cdot}1808$$
$$= 0{\cdot}1966 \text{ lb} \quad . \quad . \quad . \quad (b)$$

From Equation (2) the load for a given stress in the material is:

$$W = \frac{\pi d^3 S}{8D}$$

But $$W = \frac{lGd^4}{8ND^3} \text{ (Equation (1))}$$

$$\therefore \quad \frac{\pi d^3 S}{8D} = \frac{lGd^4}{8ND^3}$$

or $$l = \frac{\pi ND^2 S}{Gd}$$

$$= \frac{\pi \times 25 \times 0{\cdot}09 \times 20\,000}{10 \times 10^6 \times 0{\cdot}025}$$

i.e.

$$\text{maximum extension} = l = 0{\cdot}5656 \text{ in.} \quad . \quad . \quad (c)$$

Flat Springs. Flat steel springs are also extensively used in the restoration of magnet armatures, for the positioning of pawls, detents, and other moving parts of an automatic mechanism. Most of these springs are loaded as cantilevers, i.e. the springs are fixed at one end and the load is applied near the free end of the spring (Fig. 63). The deflection equation for a rectangular spring in the form of a simple cantilever loaded at the free end is

$$Y = \frac{4WL^3}{Ebt^3} \quad . \quad . \quad . \quad (4)$$

where Y = deflection (in.),
W = load at the free end (lb),
L = length of cantilever between load and fixing (in.),
E = modulus of elasticity,
b = breadth of material (in.),
t = thickness of material (in.).

The modulus of elasticity depends upon the material used, the following being typical values for spring materials:

Material	Modulus of Elasticity (E) (lb/sq in.)
Carbon Steel Wire . .	29×10^6
Staybrite (Stainless Steel) .	28×10^6
Nickel Silver . . .	18×10^6
Phosphor Bronze . .	15×10^6

For a spring of rectangular cross-section, the maximum stresses occur at the upper and lower surfaces. With a spring loaded as in Fig. 63 the upper surface is subject to a tensile stress, whilst the lower surface is under compression. The maximum stress (for a spring of rectangular cross-section) is given by:

$$\text{Stress} = S = \frac{6WL}{bt^2} \text{ (lb/sq in.)} \quad . \quad (5)$$

where the symbols have the same meaning as in Equation (4).

As in the case of a helical spring, care must be taken to ensure that the material is not stressed beyond the elastic limit.

EXAMPLE. A flat steel spring, 0·4 in. wide and 0·02 in. thick, is to be used for restoring the armature of the vertical magnet in a 2-motion selector. The spring is rigidly fixed at one end and the load is applied perpendicular to the flat surface of the spring at a point 2·5 in. from the fixing. The armature movement at this point is 0·3 in.

What deflection of the spring must be provided when the armature is normal to produce a restoring force of 0·5 lb when the armature is fully operated? It may be assumed that the modulus of elasticity of the spring material is 25×10^6 lb/sq in.

From Equation (4), the *total* deflection of the spring to produce the maximum restoring force is:

$$\begin{aligned} Y &= \frac{4WL^3}{Ebt^3} \\ &= \frac{4 \times 0{\cdot}5 \times 2{\cdot}5^3}{25 \times 10^6 \times 0{\cdot}4 \times 0{\cdot}02^3} \\ &= 0{\cdot}3906 \text{ in.} \end{aligned}$$

Thus, the total deflection of the spring must be 0·3906 in. to produce a maximum restoring force of 0·5 lb. The spring deflects 0·3 in. during the armature travel and hence the spring must be adjusted to have a deflection of 0·3906 − 0·3 = 0·0906 in. when the armature is normal.

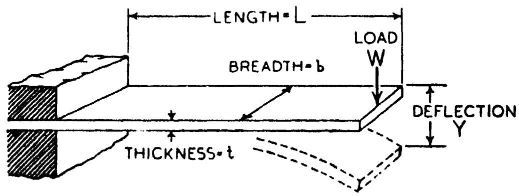


FIG. 63. FLAT SPRING

Contact Springs. Automatic switching circuits require the use of a number of contact springs which are operated mechanically during the functioning of the selector mechanism. For example, it is necessary to provide contacts which will change over the circuit conditions when a 2-motion selector moves from normal and also when the wiper carriage is moved to the first rotary position. Other contacts are required to operate when the selector magnet is energized. These mechanically operated contacts are generally similar to the contacts of telephone relays. The contact springs are of the flat cantilever type and are arranged in the usual units to provide make, break, changeover, etc., combinations. Modern practice favours the use of twin contacts to increase the circuit reliability (see Volume I).

Each spring of a contact unit is clamped at one end, and can be considered as a free cantilever before the contacts are closed, and as a beam fixed at one end and held at the other end by an elastic support after the contacts have closed. The performance of a complete spring set is somewhat complex and is not appropriate to this Volume, but the deflection of each simple component cantilever can be calculated from the equation already

given for flat restoring springs (Equation (4)). For electrical contact springs, however, it is necessary to apply a correction factor due to the fact that the fixing of the cantilever is not rigid. The electrical requirements necessitate the provision of fibre or similar insulating material between each contact

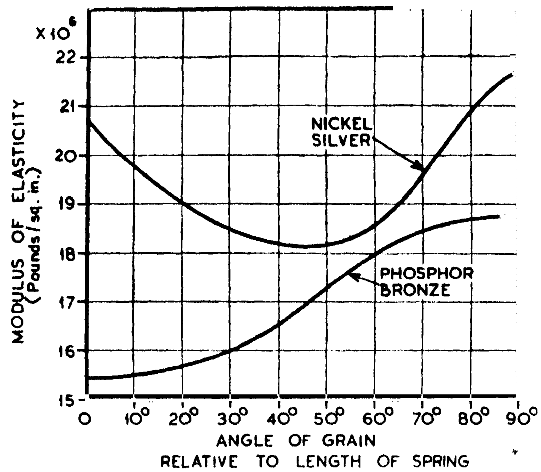


FIG. 64. VARIATION OF ELASTICITY WITH ANGLE OF GRAIN

spring. This material is comparatively soft, and the elasticity of the clamping makes it difficult to assess the effective length of the cantilever. In practice the difficulty is overcome by the application of an end correction.

Contact springs are usually constructed of nickel silver, although phosphor bronze has been used to some extent. The performance of these contact springs varies with the direction of the grain in the material. The grain is produced during the rolling process of the sheet from which the springs are cut, and care must be taken to stamp the springs in such a way that the grain is such as to produce the required characteristics. Fig. 64 shows how the modulus of elasticity of nickel silver and phosphor bronze varies with the direction of the grain. From this illustration it is clear that to obtain the maximum elasticity, it is important to avoid a 45° grain on nickel silver springs, or a grain which runs in the same direction as the length of the spring when the material is phosphor bronze.

Vibration and Contact Bounce. All automatic switch mechanisms produce a certain amount of mechanical vibration during operation. This vibration is particularly difficult to eliminate on selectors which employ a ratchet and pawl drive system. Generally speaking, the mass of the various moving parts is fairly high, and there is a considerable amount of kinetic energy to be dissipated at the end of each step. Even with the best possible design, these vibrations are transmitted to the various electrical contacts on the selector and are liable to produce microphonic effects or, worse still, to cause actual interruption of the circuits due to contact bounce. Difficulties may be experienced with the mechanically operated contacts of a 2-motion selector. These contacts are subject to a considerable degree of vibration during the stepping of the selector and there is also a tendency for vibration to be transmitted to the contact units through the various operating levers, etc.

The mechanically operated contacts of a selector are often utilized to close or open the circuit of a relay. Such circuits are highly inductive. If contact bounce occurs during the closure of the mechanically operated springs, the relay current may be interrupted several times before the circuit for the relay is finally and completely closed. The effect is shown diagrammatically in Fig. 65. The current in

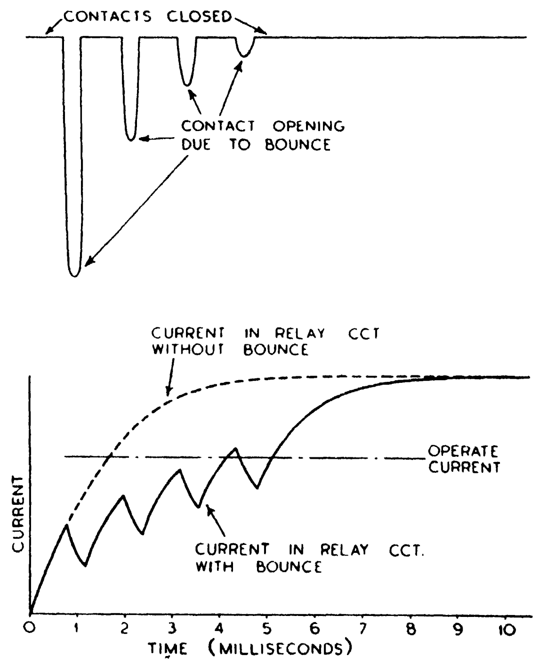


FIG. 65. SHOWING THE EFFECT OF CONTACT BOUNCE

the relay circuit commences to rise on the initial closure of the contacts, but before this current has had time to build up to a large value, the circuit is interrupted momentarily at the first bounce of the contacts. The current now decays at a rate which is dependent largely upon the degree of arcing at the controlling contacts. As the contacts reclose, the current again builds up and the process is

repeated until the magnitude of the bounce decays to such an extent that the contacts do not reopen. The net result of contact bounce is a general slowing up in the operating time of the controlled relay. This may have serious repercussions in the functioning of the circuit, especially where the timing requirements are onerous.

Contact bounce also very materially shortens the life of the contacts. At each opening of the circuit a small arc is set up, and there is local heating at the contact surfaces. If there is severe bounce, there may be a prolonged series of small arcs before the contacts finally settle down. The heating effect during this period is cumulative, and the temperature at the surface of the contacts may reach such a value that the contact material is destroyed. Contact bounce is particularly harmful to the contacts under conditions where the initial current is high.

During operation of mechanically controlled contacts, the moving springs and the system of operating levers possess an appreciable amount of kinetic energy. (The amount of energy is, of course, dependent upon the mass of the moving system and upon the final velocity.) If the moving system is suddenly arrested by a fixed contact, this kinetic energy results in a rebound of the moving system which may be sufficient to allow the contacts to reopen.

The adoption of light moving parts and the prevention of an excessive speed of closure help to minimize contact bounce. It is also desirable that the contact units should be designed so that the fixed contact can absorb as much energy as possible on closure. The design should be such that, from the moment the contacts close, the total forces tending to keep the contacts together should always exceed the forces which tend to separate the contacts.

The upper part of Fig. 66 shows typical "make" and "break" contact units. On the make unit, the moving spring is tensioned downwards towards the operating lever, but the fixed contact is a free cantilever. When the contacts close on operation, the fixed contact is deflected upwards to produce an increasing pressure against the moving contact. If this fixed spring is very flexible, the forces built up during the early stages of deflection may be insufficient to prevent bounce. If, on the other hand, the fixed spring is stiff enough to provide the requisite force during the early stages of deflection, it is difficult to prevent an excessive restoring force as the deflection is continued.

The modern tendency is to provide a buffer for the fixed spring as shown in the lower part of Fig. 66. On make contacts the fixed spring is tensioned downwards against the fixed buffer block. When the contacts close there is a predetermined downward pressure from the fixed spring as soon as the spring is lifted clear of the buffer block. It is therefore possible to use comparatively thin and flexible springs, and at the same time to obtain an adequate pressure on closure without an excessive build-up later. On break contacts the bounce difficulties are likely to occur on restoration of the spring set when exactly the same conditions occur. In this case the fixed spring is normally tensioned

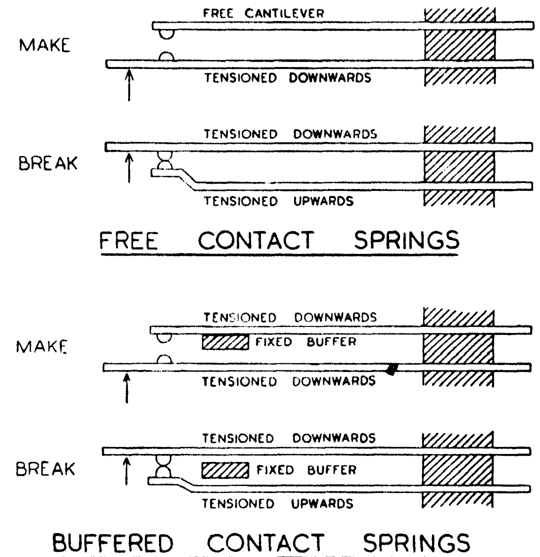


Fig. 66. Unsupported and Buffered Contact Springs

upwards against the moving spring and comes to rest on the fixed buffer when the contacts open.

There is also a danger of circuit trouble due to false contact operation resulting from the normal mechanical vibrations of the selector mechanism. The danger is greatest on springs of the free cantilever type and when the natural frequency of the spring coincides with one of the vibrational frequencies of the mechanism. The adoption of buffer blocks materially reduces this tendency to sympathetic vibration, since the spring is now supported near the extremity by the buffer.

Contact bounce can also be minimized by arranging that the moving and fixed springs of an assembly have different natural periods of vibration. This can be obtained by utilizing springs of different thickness, or by varying the lengths of the individual springs. When two springs of different resonant frequency are held in contact, they have a mutual damping effect.

Wipers and Banks. *The wipers of a step-by-step selector are particularly subject to vibration due to the sudden changes in the velocity of the wiper shaft during stepping.* This problem is especially difficult during the vertical stepping of a 2-motion selector when the wipers are clear of the bank contacts. Excessive vibration during this movement can readily cause difficulties when the wipers are required to cut into the selected level.

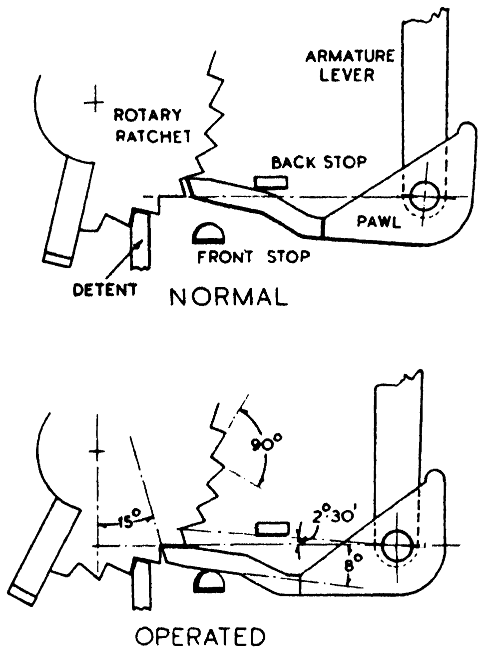


FIG. 67. DESIGN OF ROTARY RATCHET AND PAWL SYSTEM
(2000 type 2-motion selector)

Apart from the vibration transmitted to the wipers from the stepping mechanism, the wipers themselves also tend to vibrate as they ride over the bank contacts. When a wiper reaches the front edge of a bank contact, the blades of the wiper are forcibly opened and, if the velocity of this opening is sufficiently great, there may be several cycles of bounce before the wipers finally settle down on the contact. Wiper bounce can be largely eliminated by careful design. As before, the fundamental criterion is that the wipers should be of such a construction that the force tending to prevent the wiper leaving the contact (i.e. its tension) is greater, when the wiper has been deflected by the contact, than the outward force due to the acceleration of its mass. These considerations demand a wiper which is short and light, but which can be adjusted to give a high contact pressure on the bank. *The use of some form of damping on the wiper blades helps to minimize bounce.*

The materials used for the wipers and banks of a selector must give a long life and freedom from microphonic noise. Cost considerations prohibit the use of precious metal contacts, and recourse must be made to the more common materials such as brass, phosphor bronze, nickel silver, and stainless steel. A large number of selectors use brass contacts, although nickel silver is now becoming more common. It is clearly desirable that any wear should take place on the wipers and not on the bank contacts, since the former are readily replaceable and the latter are not. Nickel silver wiper blades are commonly used on selectors of various types.

The design of the wiper tip is of some importance. The shape of the tip determines the outward accelerating forces of the wiper blades when a contact is encountered, which in turn determines the liability to bounce. Moreover, many years of experience have shown that certain types of wiper tip are less liable than others to produce microphonic noise and circuit failures due to dirt, grit, etc., on the bank contacts. The detailed design of the wipers of both uniselectors and 2-motion selectors is considered in later paragraphs.

Design of Ratchet and Pawl System. The ratchet and pawl system is probably the most important part of any step-by-step selector mechanism. Very great care must be taken in the selection of the materials and in the dimensioning of the various parts to obtain reliable stepping with a minimum of wear. The design is somewhat complicated by the fact that the mechanisms must (at least in the Post Office standard system) perform satisfactorily under the control of dial impulses, and also under automatic drive conditions.

The essential components of a ratchet and pawl system are:

(*a*) A ratchet wheel rigidly attached to the wiper assembly and provided with suitable teeth with which the pawls and detents can engage.

(*b*) An operating pawl attached to an extension of the operating magnet armature.

(*c*) Front and back stops which limit the extent of the pawl movement during the operation of the magnet armature.

(*d*) A means of interlocking the pawl and ratchet wheel at the completion of each step. If this were not provided there would be a tendency for the wipers to overrun the bank contacts due to the momentum of the moving system.

(*e*) A detent which engages with the ratchet teeth to prevent a reverse movement of the wipers during the return stroke of the pawl. In some cases

this detent also holds the wipers in position against the tension of a wiper shaft restoring spring.

(*f*) Springs for holding the pawl and detent in close contact with the ratchet wheel.

Fig. 67 shows the detailed design of the rotary ratchet and pawl system of a modern (2000 type) 2-motion selector. The pawl is mounted on a bearing at the end of the armature lever, and a suitable spring (not shown in Fig. 67) maintains the pawl in contact with a tooth of the ratchet wheel. A pawl guide or back stop is provided to regulate the normal position of the pawl, and the pawl tip itself is case hardened to prevent wear. When the electromagnet is energized, the attraction of the armature and the consequent movement of the armature lever moves the pawl tip into contact with the short face of the ratchet tooth, and further movement rotates the ratchet wheel in a clockwise direction. Towards the end of the armature stroke, the pawl engages with the front stop so that it is lightly wedged between the ratchet wheel and the stop. This wedging action prevents any "overthrow" of the wiper assembly due to the momentum of the moving system. The wedging angle (i.e. the angle between the projected longer face of the ratchet tooth and the line of the pawl face engaging with the back stop) is carefully adjusted to reduce wear on the ratchet to a minimum.

An important point in the design of a ratchet and pawl system is the prevention of "pawl throw-out." This trouble is likely to occur if the forces exerted on the tip of the pawl during operation tend to throw the pawl out of engagement with the ratchet tooth. The tendency to throw out during operation is minimized by arranging that the pawl engages with the ratchet wheel some 15° from the tangential position. The teeth themselves have a comparatively blunt apex angle, and are so cut that neither flank is radial. The plane of the long flank of the tooth is such that it is in a direct line with the axis of the pawl so that, during the armature return stroke, the pawl has no momentum in a rotary sense about its own pivot. Hence there is no tendency for the pawl to leave the ratchet wheel during the return stroke, and a comparatively weak pawl spring suffices to ensure that the pawl engages satisfactorily with the next tooth of the ratchet wheel.

The rotary detent is spring loaded against the ratchet wheel, and during movement of the latter the tip of the detent slides along the long face of the ratchet tooth. At the end of the stroke the detent slips over the apex of the tooth to prevent displacement of the wiper assembly during the return movement of the operating pawl.

Fig. 68 shows the detailed design of the ratchet and pawl system of a reverse-acting uniselector mechanism. (The design shown is that of the P.O. No. 2 type heavy-duty uniselector—Fig. 83.) It will be noted that the pawl tip engages with a tooth well forward so that the tip of the pawl locks behind the slope of the tooth during the return movement of the pawl. This ensures that the pull exerted by the pawl when rotating the ratchet does not produce an expelling force on the pawl itself. The dimensions of the wedging angle and the design of the pawl back stop are chosen to provide positive

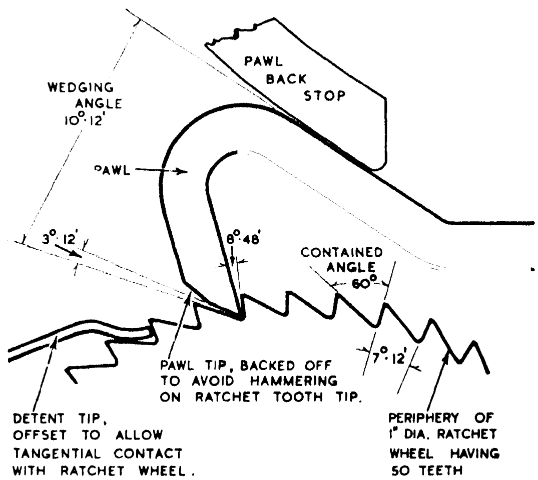


FIG. 68. DETAILS OF RATCHET AND PAWL SYSTEM
(Reverse-acting uniselector)

stopping at the completion of each step, but at the same time to minimize the danger of "stalling" (i.e. the condition where the pawl locks between the ratchet teeth and the back stop in such a way that the next operation of the pawl is prevented). The portion of the pawl which engages with the back stop is given a slight camber so that the wedging force is always applied along a line central with the pawl tip—irrespective of slight lateral displacements of the pawl or back stop. The pawl tip is case hardened and is "backed off" to avoid hammering on the tip of the ratchet teeth.

The detent of a uniselector type mechanism can either be of the hook type or of the straight type. Detents of the hook type can be designed to engage with the root of the ratchet teeth so that the adjustment is substantially unaffected by wear at the tips of the teeth. Such detents cannot, for physical reasons, be placed close to the pawl, and it is difficult to arrange the design so that both pawl and detent are reasonably accessible for maintenance. The flat spring type of detent can, however, be located on the same side of the ratchet

as the operating pawl. In Fig. 68 the detent spring is offset so that its tip rests squarely on the short face of the ratchet tooth. The tip is so shaped that the detent rides on the long face of the tooth during movement of the ratchet wheel (and not along the tip of the tooth which tends to produce excessive wear). This arrangement ensures that there is a minimum of wear, and also that the adjustment of the detent is unaffected by wear at the ratchet tooth tips.

Magnet Design. The electromagnet of an automatic selector provides the necessary energy to overcome the frictional forces, spring tensions, etc., of the mechanism. The tractive force of any electromagnet is given by:

$$\text{Force} = \frac{B^2 A}{8\pi} \text{ dynes}$$

where B = flux-density in the armature air gap (gauss),

A = area of magnet pole face (sq cm).

But 981 dynes = 1 gramme.

Therefore

$$\text{tractive force} = \frac{B^2 A}{24\ 658} \text{ grammes}$$

$$= \frac{B^2 A}{11{\cdot}44 \times 10^6} \text{ lb.}$$

The flux-density in turn depends upon the magnetomotive force of the winding, and the reluctance of the magnetic circuit. The magnetomotive force is directly proportional to the number of ampere-turns,

i.e. $\quad$ m.m.f. = $1{\cdot}257\ NI$ (Gilberts)

where I = current in amperes,

N = number of turns.

The reluctance of the magnetic circuit is made up of the separate reluctances of each part of the flux path, i.e. it is the total reluctance of the magnet core, yoke, armature, and armature air gap. Under any given conditions the reluctance of the circuit can be calculated from a knowledge of the physical dimensions of each part of the magnetic circuit and the permeability of the material. For each portion of the circuit:

$$\text{Reluctance} = \frac{L}{A\mu} \text{ (Oersteds)}$$

where L = length of path (cm),

A = cross-sectional area of path (sq cm),

μ = permeability of material.

Most of the reluctance of the magnetic circuit is due to the armature air gap, and small changes in the length of this gap can produce very material variations in the tractive force for a given number of ampere-turns. During the operation of the magnet armature, there is a rapid reduction in the length of the air gap and a corresponding reduction in the reluctance of the magnetic circuit. This in turn causes the tractive force of the magnet to increase sharply as the armature is attracted towards the core face. Since the reluctance of the magnetic circuit is largely concentrated in the air gap, the value of B varies approximately inversely with the length of the gap. Hence, for a given number of ampere-turns, the tractive force of the magnet at any particular instant is approximately inversely proportional to the square of the armature air gap.

The forces to be overcome by the electromagnet also vary from instant to instant during the operation of the mechanism. It is therefore necessary to carry out a detailed study of the tractive force of the magnet and the variation of the load on the magnet throughout the cycle of operation. Such a study can perhaps best be made by the use of a simple force-movement diagram as shown in Fig. 69. For purposes of illustration it is assumed that the mechanism is of the reverse-acting type, i.e. the operation of the electromagnet does not move the mechanism directly, but tensions a spring so that, when the electromagnet is de-energized, the energy stored in the spring can be used to carry out the required selective movement.

The curve AE shows how the tractive force of the electromagnet increases during the travel of the armature. The broken line AF indicates the tension of the armature restoring spring, the value of A being the initial tension which gradually increases to the value F as the spring is extended. When the current is first connected to the electromagnet, the tractive force increases gradually (due to the inductance and eddy current effects in the magnet) until it exceeds (at point A) the initial tension of the armature restoring spring. At this point the armature commences to move and there is a build-up both of the magnet tractive force and of the restoring spring tension. Movement of the armature causes a deflection of the pawl spring as the pawl rides up the ratchet tooth. This increases the load on the armature so that the rise of load follows the line AB.

It is assumed that there is a pair of simple interrupter contacts which are operated by an extension of the armature fairly late in the stroke. At point B the tension of the moving spring of the interrupter contacts builds up rapidly as the

contacts open, and very soon the armature is carrying the load of the main restoring spring, of the pawl spring and of the interrupter contacts simultaneously. This load continues to rise as the several springs are tensioned or deflected, until point *C* is reached. At this point the pawl reaches the tip of the ratchet tooth and falls into the next tooth. This produces a small reduction in the armature load as shown by the slight fall at *C*. From this point onwards until the end of the stroke the load on the armature continues to rise steadily. Frictional forces during the operation of the armature are small in comparison with the remaining load and have therefore been neglected.

It is clear that at any particular point in the armature stroke, the margin of safety on the mechanism is determined by the distance between the curve showing the magnet pull (*AE*) and the load curve (*ABCD*). If at any point these two curves become close together, then there is a danger of failure at that point. The difference between these two curves also shows the accelerating force on the armature. It will be seen from Fig. 69 that the accelerating force is comparatively small when movement starts but becomes progressively greater as the armature is attracted.

The lower portion of Fig. 69 shows the conditions during release of the armature. The broken line (*ANFCD*) shows the tractive force produced by the armature restoring spring augmented by the pressure of the interrupter contacts (portion *FCD*). During the early part of the return stroke there is no appreciable load (except frictional losses) until such time as the pawl engages with the front of the ratchet tooth and commences to move the wiper assembly. At this point (*G*) there is a sudden load on the armature due to the friction between the wipers and the contact banks. As the wipers are moved along the bank contacts, this frictional load is increased slightly by the deflection of the ratchet detent. At point *H* the non-bridging wipers leave the bank contacts, thereby causing a sudden and material reduction in the armature load. The bridging wipers, however, maintain a fairly constant load as they pass from one contact to the next. At point *J* all the wipers reach the edge of the next set of bank contacts, and there is a very large increase in load due to the deflection of the wiper blades as the latter are moved on to the contacts (*LK*). When the wipers are properly positioned on the contacts, the total load is again reduced to the frictional level, and this load is substantially maintained until the armature reaches normal. Almost at the end of the stroke the fixed detent falls into the next ratchet tooth and causes a slight reduction in the load (*M*).

Under the conditions assumed in Fig. 69 the danger of failure is greatest when the wipers are just moving on to the next set of bank contacts. At this point there is very little difference between the armature restoring force and the load (*NL*). Any excess wiper pressures or any weakness of the

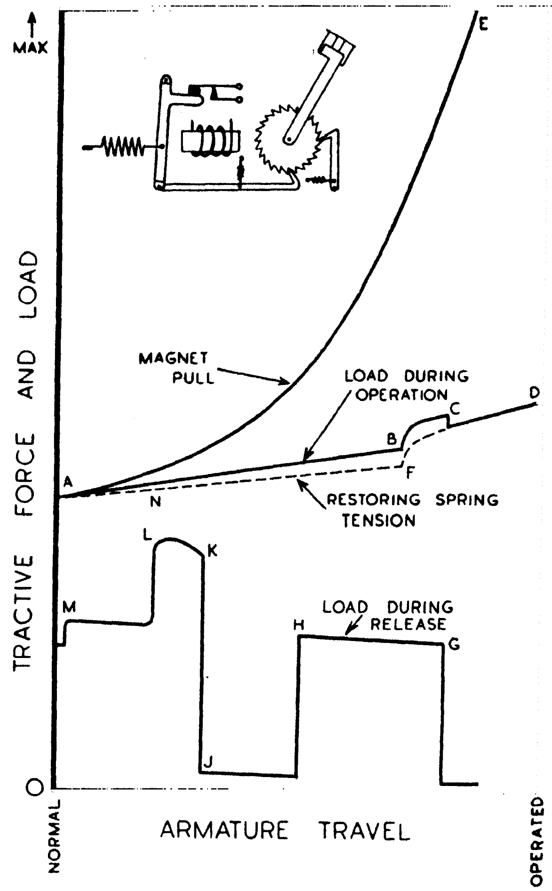


FIG. 69. RELATIONSHIP BETWEEN MAGNET PULL AND LOAD OF A TYPICAL STEP-BY-STEP SELECTOR

restoring spring could easily produce failure at this point.

It is possible to produce similar diagrams for every type of mechanism—the only difficulty being to assess the various frictional and other forces present throughout the cycle of operations. Not only does such a diagram enable the margin of safety to be readily determined, but it also permits calculations of the acceleration and ultimate velocity of the armature. In the example quoted, there is a very material margin between the magnet pull and the restoring spring, etc., load towards the end of the operate stroke. Such a big difference

will cause rapid acceleration of the armature with the resultant high velocity at the end of the stroke If this high velocity is accompanied by a large mass of the moving system there is a considerable amount of kinetic energy to be dissipated at the end of the stroke. The design of the mechanism must be such that this energy can be dispersed without causing abnormal wear. On the other hand, a high degree of armature acceleration may be desirable by the timing requirements of the circuit.

Operating Conditions of Selector Magnets. Automatic switching mechanisms of the step-by-step type are required to respond to impulses of the Strowger type. It has been seen that the standard impulse consists of a break period of $66\frac{2}{3}$ msec with a period of $33\frac{1}{3}$ msec between successive impulses. The selector is required to complete one step in the process of selection during the $66\frac{2}{3}$ msec period, and to restore in readiness for the next step during the following make period of $33\frac{1}{3}$ msec.

Although the magnet is *nominally* energized for some 66 msec and released for 33 msec, the actual length of the current pulse to the magnet may be considerably shorter (or the time between successive pulses may be shorter) due to variations in dial speed or ratio, and impulse distortion due to the line conditions and the response of the impulse accepting relay. There must also be a reasonable factor of safety so that, in practice, the selector will function satisfactorily for long periods under the most adverse conditions and with a minimum of maintenance attention.

If the magnet of a forward-acting mechanism is energized for too short a period, the mechanism may step, but if the armature pawl does not lock with its front stop there is a danger that the shaft may overstep. Overstepping is, in fact, a sure sign that the operating pulse to the magnet is of insufficient duration. If, on the other hand, the period between pulses to the magnet is too short there is a possibility that the selector magnet will fail to release sufficiently to allow the pawl to engage with the next ratchet tooth. This results in understepping of the mechanism. It should be appreciated that, so far as the mechanism is concerned, the actual *length* of the current pulses applied to the selecting magnet and the time between such pulses are the limiting factors. As will be seen later, impulse *ratio* and impulse *frequency* are important in the design of the circuit, but these have only an indirect effect on the performance of the mechanism.

A number of factors influence the speed of response of a selector mechanism. On the mechanical side the mass of all moving parts must be kept as small as possible to minimize the inertia of the moving system. The volume of metal in each part of the moving system must, however, be sufficient *to withstand the forces to which that part is subjected. If the mass is reduced beyond this limit,* then excessive wear may occur and abnormal maintenance attention may be necessary.

Apart from the mechanical arrangements of the switch, the design of the electromagnet has quite a large influence upon the performance. In the first place, the magnet must produce a sufficient tractive force to overcome the load and to impart an adequate velocity to the moving system. It is even more important that there should be a rapid growth of flux when the magnet is energized.

Inductance of Magnet. With a mechanism of fixed design, a certain number of ampere-turns are required to produce the necessary tractive force to actuate the mechanism. This tractive force can be provided by a small current through a magnet winding consisting of a large number of turns. The same tractive force can, on the other hand, be produced by a magnet of a lower number of turns but with a correspondingly higher value of current. With an exchange battery of fixed voltage, the current is determined wholly by the resistance of the magnet ($I = E/R$). Hence:

$$\text{Tractive force} \propto IT \propto T/R$$

where T = number of turns,
R = resistance.

If the resistance of the winding is doubled, the number of turns must also be doubled to produce the same tractive force. But the operate time of an electromagnet is determined by its time constant, i.e. by its L/R ratio. The inductance (L) is, however, dependent upon the *square* of the number of turns (T^2), and hence if the resistance of the magnet winding is doubled, the number of turns must also be doubled, which results in a four-fold increase of inductance. Thus, doubling the resistance produces a magnet winding of four times the inductance, and the time constant of the circuit is twice the previous value. If, on the other hand, the resistance of a magnet winding is reduced to one-half, the inductance is reduced to one-quarter for the same number of ampere-turns, and the time constant is one-half the previous value. It is clear, therefore, that to obtain the minimum operate lag, the magnet winding should have as low a resistance as possible.

This requirement is illustrated in Fig. 70 which shows typical curves for the growth of current in a magnet circuit of a modern 2-motion selector. Each coil is designed to produce 1200 ampere-turns at 46 V when the current has reached its maximum value. If it is assumed that the mechanism will

operate with 480 ampere-turns, these curves show that the current in a coil of 12·5 Ω reaches the operate value in a period of about 1 msec, whereas a similar coil with the same tractive force but of 200 Ω resistance requires some 10 msec for the current to reach the operate value.

The reduction of magnet resistance to provide a high speed of operation introduces other problems. In the first place, as the resistance is decreased the current in the magnet coil becomes so great that it is difficult to provide suitable contacts on the controlling relay which are capable of making and breaking the high value of current. Moreover, a low resistance winding must be carefully designed to avoid the risk of fire (or, at least, of burn-out), should the current be accidentally applied for a prolonged period. These two factors determine the lower limit to the resistance of a magnet winding. The use of platinum contacts on the controlling relay enables reasonably high currents to be

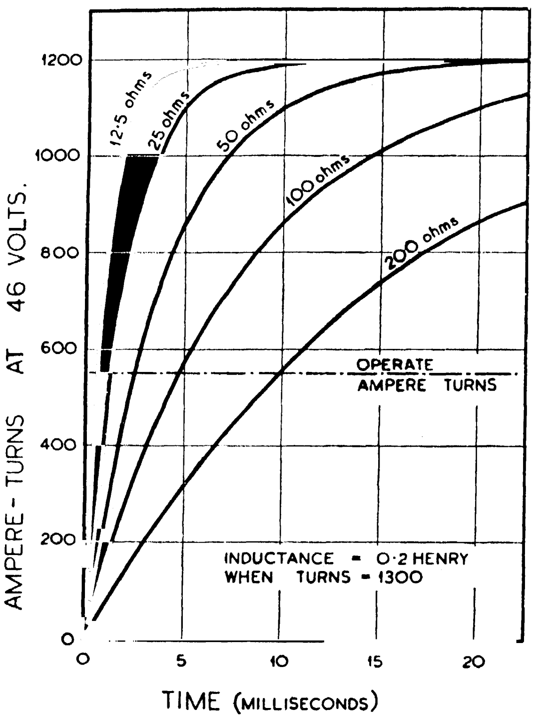


FIG. 70. EFFECT OF MAGNET RESISTANCE ON OPERATING TIME

handled, and the temperature rise in the magnet can be minimized to some degree by a mechanical design which provides for a high rate of heat dissipation.

In practice, selector magnets usually have a resistance of the order of 50 Ω and require a current of about 1 amp for their operation. Magnets of this resistance can be designed so that there is no risk of fire, and reasonable freedom from burn-outs due

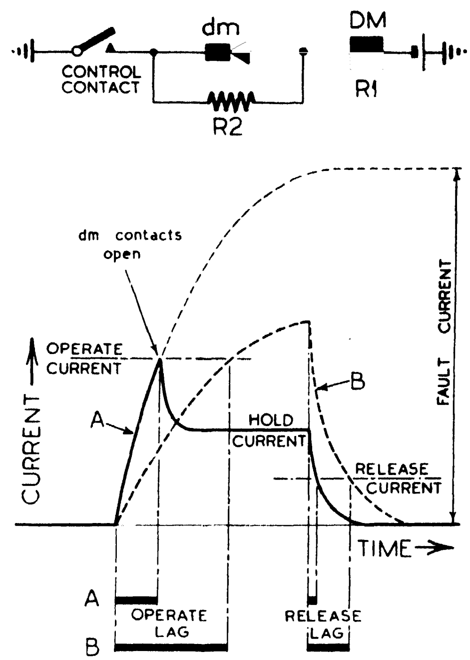


FIG. 71. METHOD OF OBTAINING SHORT OPERATE LAG BY THE USE OF MAGNET INTERRUPTER CONTACTS

to accidental prolongation of current in the winding. (Components which fulfil these conditions are often referred to as *self-protecting*.)

From time to time various devices have been suggested for minimizing the operate time of selector magnets. One such suggestion is illustrated in Fig. 71. In this circuit the selector driving magnet is of very low resistance, so that the current rapidly rises to the operate value. At this point a pair of interrupter contacts (*dm*) operate to insert a resistor (*R*2) in series with the magnet coil, thereby reducing the current to a value just slightly above the hold current of the magnet. The resultant current waveform is shown at *A* and compares very favourably with the normal type of waveform *B* which would result from the use of a higher resistance winding. The use of this circuit not only minimizes the operate lag of the magnet but, by reducing the current after operation to a value only slightly above the release current, the release lag of the magnet is also materially reduced. The disability of the circuit arrangement shown in Fig. 71 is the danger of overheating and possibly fire, should the interrupter contacts fail to break

due to any mechanical defect. Protection against fire risk is an important aspect of telephone exchange design, and the importance of this matter has so far prevented the adoption of the circuit arrangement shown.

Eddy Currents in Magnet. There is still another factor which tends to produce a time delay in the operation of a selector magnet. When the current in the magnet coil rises, the resultant flux embraces the solid metal parts of the magnetic circuit. This in turn produces eddy currents which themselves have a magnetic effect which opposes that of the original magnet current. At the end of the impulse, the interruption of the current in the magnet coil causes the flux linked with the magnetic circuit to decay rapidly, and eddy currents are again set up

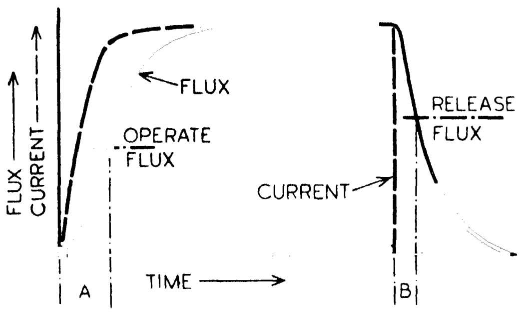


Fig. 72. Effect of Eddy Currents on Operate and Release Lags of Magnet

which tend to prolong the flux. In Fig. 72 the broken line shows the rise of current in the inductive magnet winding, and the sudden interruption of this current at the end of the impulse. The full line shows the effect of the eddy currents in delaying the rise of flux at the commencement of the impulse, and in prolonging the flux at the end of the pulse. Eddy currents therefore lengthen both the operate time (A) and the release time (B) of a magnet.

The eddy current effects can be minimized by utilizing a laminated magnetic circuit as in transformer practice. Various designs of such cores have been tried out but, generally speaking, the advantages to be gained are more than outweighed by the manufacturing and assembly difficulties. An alternative method of minimizing the eddy currents is to utilize a material for the magnetic circuit which has a high specific resistance. In the more recent designs of selectors cast iron has been found to produce the best overall results. This material has a reasonable permeability and a very high electrical resistance which, under any given conditions, minimizes the value of the eddy currents.

The vertical magnet of a modern (2000 type) selector with, say, up to 4 banks, will operate satisfactorily with a minimum current pulse of the order of 30 msec, and will release within 12 msec. The vertical magnet of pre-2000 type mechanisms has a slightly longer operate lag (about 33 msec) but a somewhat shorter release lag (about 7 msec). In each case the rotary magnet has a better operate performance than the vertical magnet, due to the absence of gravitational forces during rotary stepping.

Spark Quenching. When a current flows in an inductive circuit, energy is stored in the magnetic field produced by the passage of the current through the inductance. It can be shown that the amount of energy stored is dependent upon the value of the inductance and upon the *square* of the current flowing through it. If the inductance is L henrys and the current is I amperes:

$$\text{stored energy} = \tfrac{1}{2}LI^2 \text{ joules}$$

The electromagnets of automatic selectors do not (by design) possess a very great inductance but the high value of current nevertheless results in the storage of a considerable amount of energy. When the current ceases at the end of each impulse, this electromagnetic energy must be dissipated in a way which will not cause damage to the magnet windings or to the associated circuits and controlling contacts. Moreover, it is important that the method of dissipation should be such that there is as little interference as possible with the release of the magnet.

When the current in an inductive circuit is interrupted, the energy stored in the magnetic field is released in the form of an e.m.f. the value of which depends (for a given inductance) upon the rate of current decay. If the disconnexion at the relay contacts is instantaneous and complete, the induced e.m.f. is (theoretically) infinitely great, but in practice although the break may occur very quickly it is never absolutely instantaneous. Even after the actual metallic contact is broken, the initial minute air gap is to some degree conducting and provides a path for the current for a short time after the actual disconnexion. The high rate of current decay can, nevertheless, give rise to induced voltages which may be dangerous. For example, the inductance of a 2000 type selector magnet is of the order of 0·75 H and the normal current is about 1 A. If the design of the controlling relay is such that the current is interrupted within a period of, say, 0·5 msec, then the induced e.m.f. is roughly $0{\cdot}75 \times 1/0{\cdot}0005 = 1500$ V.

The induced e.m.f. may be sufficiently great to cause breakdown of the insulation of the magnet

wiring or its associated circuit, and at the best will produce a spark at the controlling relay contacts which by ionizing the short air path allows an arc to form at the relay contacts. If such arcing is allowed to persist, the relay contacts overheat and are rapidly destroyed. Hence, all automatic selector magnet circuits and a few highly inductive relay circuits are provided with a spark quench circuit through which the inductive energy can be dissipated so as to avoid dangerous induced e.m.f.s and arcing at the relay contacts.

Resistive Spark Quench Circuit. Possibly the simplest form of spark quench circuit is a non-inductive resistance across the selector magnet as shown in Fig. 73. Contact $A1$ releases at the commencement of a break impulse period and the current i_1 through the magnet rises in accordance with Helmholtz's equation:

$$i_1 = I_m\,(1 - \varepsilon^{-\frac{r}{L}t})$$

where i_1 = the value of current (amperes) after t seconds,
I_m = maximum value of current (amperes),
r = resistance of circuit (ohms),
L = inductance of circuit (henrys).

After a predetermined time the current reaches the operate value (OC) for the magnet, thereby producing an operate lag (OL). It should be noted that at the moment the circuit is completed ($t = 0$) the initial current through the $A1$ contact is limited to the Ohm's law value of current through resistance R. Hence any contact bounce on the release of $A1$ does not produce any appreciable arcing at the contacts.

At the end of the impulse period, **A1** re-operates and breaks the magnet circuit (point B in Fig. 73). As the current begins to fall, the induced e.m.f. in the magnet winding produces a circulating current through the spark quench resistor R; the current (according to Lenz's law) being in the same direction as the normal current through the magnet. The induced current decays in accordance with Helmholtz's law, i.e. assuming that the current has attained its maximum value before interruption, then the current at any instant (t) is:

$$i_2 = I_m\,\varepsilon^{-\frac{R+r}{L}t}$$

It is clear that, with fixed values of magnet resistance and inductance, the rate of decline of current is dependent upon the value of the spark quench resistance R. A high value of R produces a more rapid decline of current than a smaller value.

It has already been stated that the operate and release lags of stepping magnets should be as low as possible to give the maximum impulsing margins. The more rapid the decline of current, then the shorter is the release lag (RL) for any given value of release current (RC). From an impulsing point of view, therefore, the value of the spark quench resistance should be as high as possible to minimize the release lag of the magnet. On the other hand, the lower the value of the spark quench resistance, the more effective is the spark quench circuit.

Under given conditions there is a maximum induced e.m.f. at the $A1$ contacts above which

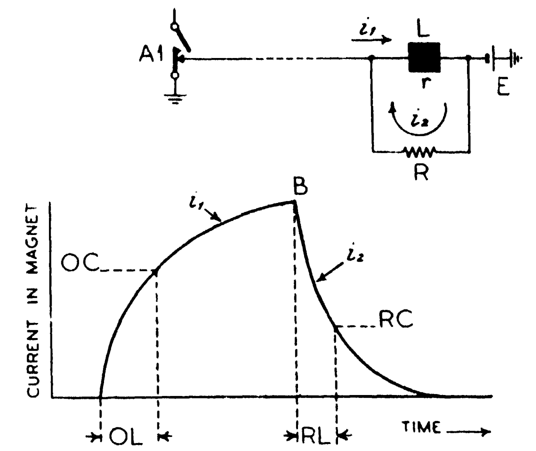


FIG. 73. DECAY OF MAGNET CURRENT WITH RESISTIVE SPARK QUENCH CIRCUIT

serious sparking and arcing will occur. It is clear that the higher the value of R, the higher is the e.m.f. appearing at the relay contacts. At point B (Fig. 73) the normal magnet current is interrupted by the operation of **A1**. If a discharge through the opening contacts is to be avoided, the spark quench circuit must *at that instant* allow the continuance of the normal magnet current of 1 A. It is true that the current through the spark quench circuit dies away logarithmically, but its maximum value is nevertheless 1 A. The initial p.d. across the magnet at the moment of break can readily be calculated from a knowledge of the magnet current and the value of the spark quench resistance. With a magnet current of 1 A and a spark quench resistance of, say, 100 Ω, the p.d. across the magnet at the moment of disconnexion is $1 \times 100 = 100$ V (Ohm's law). The p.d. across the impulsing contacts is the battery potential plus the p.d. across the magnet, i.e. $100 + 50 = 150$ V. Similarly, if the spark quench resistance is increased to 200 Ω

then, with the same value of magnet current, the maximum p.d. across the impulsing contacts at the moment of break is $(1 \times 200) + 50 = 250$ V. It should be noted that if the magnet were of, say,

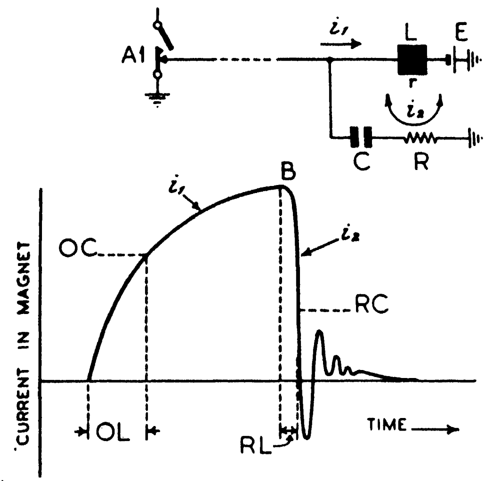


FIG. 74. RAPID DECAY OF MAGNET CURRENT OBTAINABLE BY CAPACITOR SPARK QUENCH CIRCUIT

500 Ω resistance instead of 50 Ω, a spark quench resistor of 10 000 Ω (200/0·02) would suffice to limit the maximum p.d. at the $A1$ contacts to 250 V.

It has been shown above that the value of a spark quench resistance should be as low as possible to minimize the induced e.m.f. at the contacts of the controlling relay. On the other hand, the spark quench resistance should be as high as possible to minimize the release lag of the magnet. There is a further complication due to the presence of the spark quench resistance in the operating circuit of the magnet. If the value of R is small, then consideration must be given to the extra current flowing through the $A1$ contact. The extra load is non-inductive but may produce arcing if contact bounce is present. A spark quench circuit must necessarily be a compromise between the several conflicting requirements, and the most suitable value of resistance is usually determined by practical trials rather than by theoretical calculations.

The simple resistive spark quench circuit is quite satisfactory for circuits such as the release magnet of pre-2000 type selectors and for application to certain relay circuits but is impracticable for selector stepping magnets. In such circumstances a high speed of release is required and it is not possible to obtain the necessary low release lags as well as satisfactory spark quenching.

Capacitor Spark Quench Circuit. The inclusion, as in Fig. 74, of a capacitor (C) in the spark quench circuit provides a more rapid means of dissipating the inductive energy of a selector magnet. Prior to the commencement of an impulse (i.e. with **$A1$** operated), capacitor C is charged to the voltage (E) of the exchange battery. When, at the start of an impulse, $A1$ releases, the current (i_1) in the magnet rises in accordance with Helmholtz's law. At the same time the capacitor discharges to the earth at the $A1$ contacts. The maximum value of this discharge current depends (for a given voltage) upon the size of the capacitor and on the value of the series resistance R. If the initial discharge current is too high, then welding of the contacts may occur, particularly if contact bounce is present. The first requirement of the spark quench circuit is that the resistance R should be sufficiently high to protect the $A1$ contacts on their release.

At the end of the impulse period, **$A1$** re-operates and disconnects the current in the magnet. By

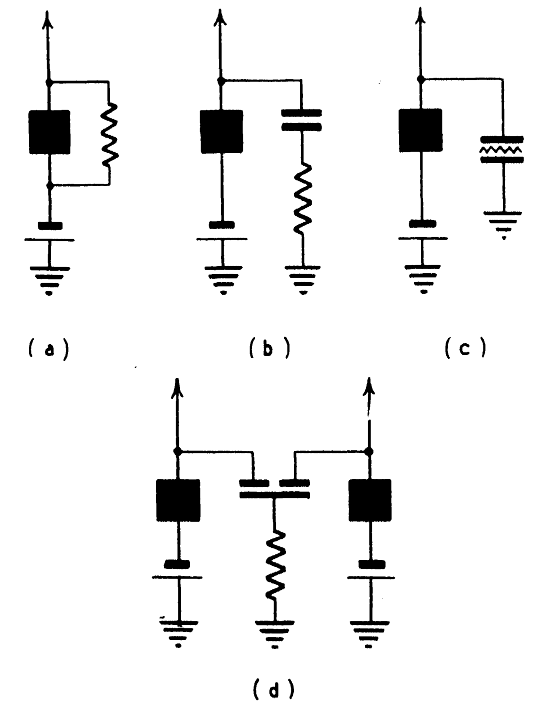


FIG. 75. TYPICAL MAGNET SPARK QUENCH CIRCUITS

this time C is substantially discharged. As before, the spark quench circuit must, at the moment of break, provide an alternative path for the full magnet current. At the same time the potential across the $A1$ contacts is the p.d. developed across the spark quench circuit due to the passage of the

magnet current (1 A). At the instant when *A*1 operates, however, the capacitor is discharged and has no p.d. across its plates. Hence the maximum p.d. across the *A*1 contacts is that due to the potential drop in resistance *R* resulting from the passage of the maximum current of 1 A. There are, therefore, two conflicting requirements in the determination of a value for *R*. The maximum limit is set by the permissible p.d. at the *A*1 contacts at the moment of their operation whilst the minimum value must ensure that the discharge current from *C* does not cause welding when contacts *A*1 release.

When *A*1 re-operates at the end of an impulse period, the inductive energy of the magnet is dissipated in a circuit containing inductance (*L*), capacitance (*C*), and resistance ($R + r$) all in series. It can be shown that if

$$\frac{(R + r)^2}{4L^2} \text{ is less than } \frac{1}{LC}$$

the currents in the closed circuit are oscillatory in character. Moreover, the degree of "damping" of the oscillations (i.e. the rate of diminution of the amplitude) and the frequency of the oscillations can be controlled by adjustment of the primary constants (*R*, *L* and *C*) of the circuit. The detailed calculations are too complex to be considered here but briefly the frequency of the oscillations varies directly with the value of

$$\sqrt{\frac{1}{LC} - \frac{(R + r)^2}{4L^2}}$$

The degree of damping depends upon the value of

$$\varepsilon^{\frac{R + r}{L}t}$$

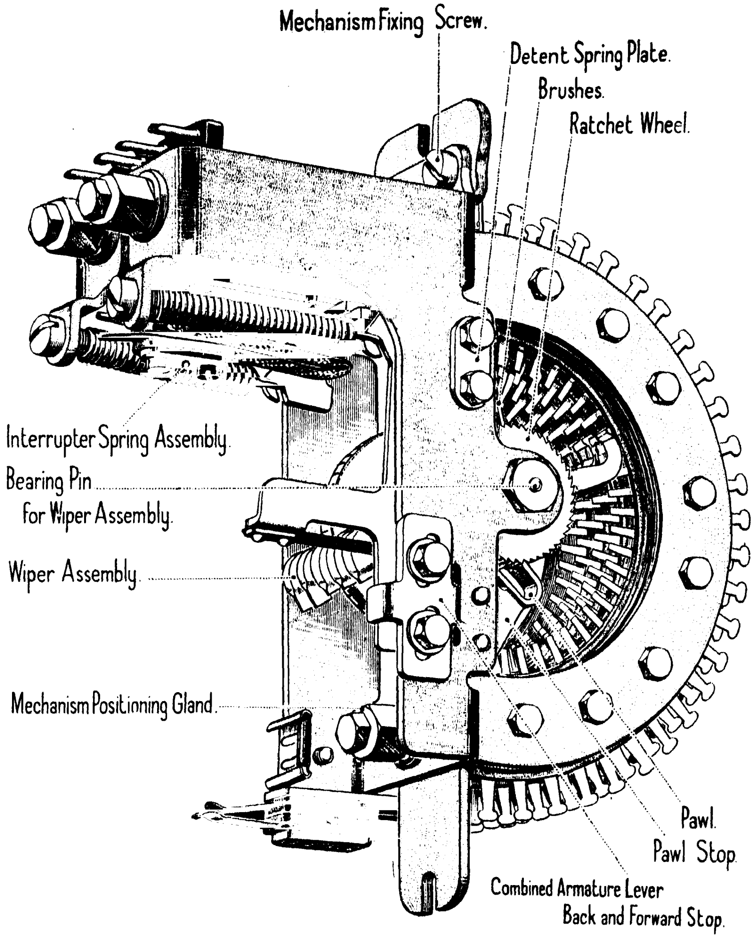


FIG. 76. P.O NO. 1 TYPE UNISELECTOR
(Viewed from right)

By suitable adjustment of the constants it is possible to obtain a steep initial decline of current (i_2) which gives a satisfactory release lag to the magnet. It should be noted that the degree of damping should be sufficient to prevent re-operation of the magnet on subsequent oscillations and also to bring the oscillatory current to zero before the next impulse to the magnet.

It will be observed that the spark quench circuit of Fig. 74 is connected to earth whilst the simple resistance of Fig. 73 is connected to battery. Some of the earlier capacitor quench circuits were connected to battery but the invariable modern practice is as shown. If in Fig. 74, *R* is connected to battery, the capacitor *C* is discharged when *A*1 is operated. The discharge current when *A*1 releases is eliminated but, on the other hand, the capacitor must now be charged concurrently with the operation of the magnet. This delays the application of the full battery p.d. to the magnet coil and increases the operate lag—a very undesirable result and one to be avoided if possible. The connexion of *R* to earth involves the charging of capacitor *C* during the time when a rapid decay of current through the magnet is required. The oscillatory currents in the quench circuit are, however, sufficiently great to swamp the

charging current and there is little increase in release lag.

Fig. 75 shows several practical arrangements of spark quench circuits. At (*a*) the quench circuit is a simple non-inductive resistance and is used only on selector release magnets and in similar circumstances where critically short release lags are not required. A 500 Ω shunt is typical for a 100 Ω release magnet and the resistance is often combined with the magnet winding. Circuit (*b*) shows the usual spark quench circuit for the vertical or rotary magnet of a selector. The capacitor is usually of 1 μF capacity and the resistor is 200 Ω. In most selector circuits the vertical and rotary magnets are never operated concurrently and in these circumstances it is possible to effect some economies by combining the spark quench circuits of the two magnets. Diagram (*d*) shows a frequent arrangement with a $1 + 1\mu$F capacitor and a common 200 Ω resistor. Circuit (*c*) shows the usual spark quench circuit for uniselector switches. The capacitor is of 0·5 μF and, for the sake of economy, includes an inherent resistance which varies from 9 to 70 Ω when measured at 1000 c/s. Where one spark quench circuit can be made to serve two adjacent uniselector circuits, a divided capacitor of $0{\cdot}5 + 0{\cdot}5$ μF with inherent resistance is employed. Spark quench circuits are required for all selector and uniselector magnets but, for the sake of simplicity, they have been omitted from a number of the basic circuit elements in this volume.

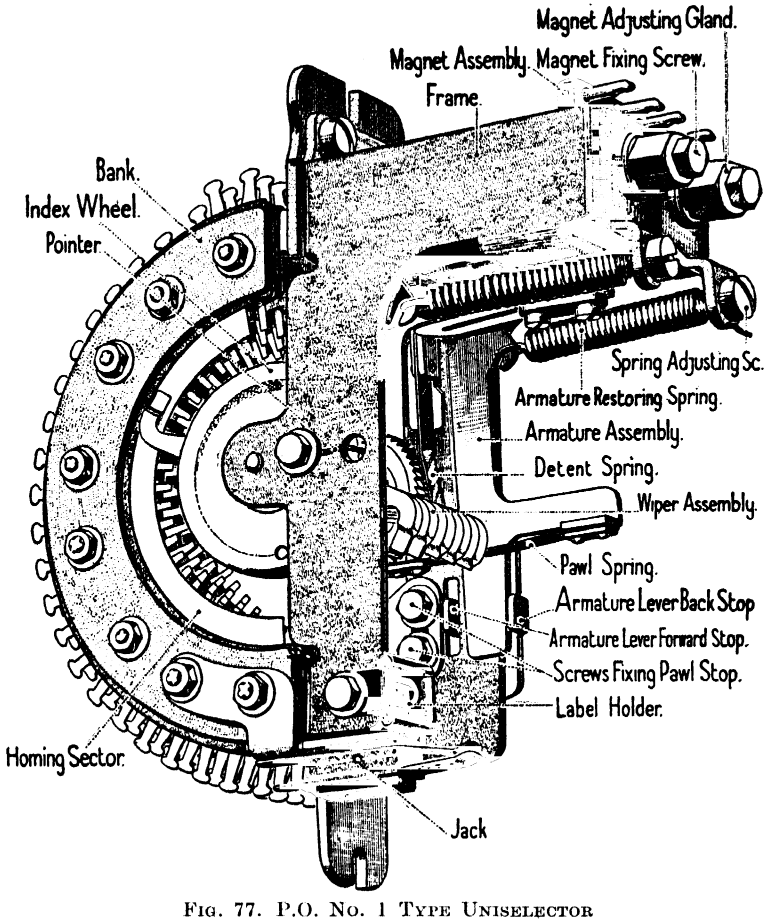


Fig. 77. P.O. No. 1 Type Uniselector (Viewed from left)

The P.O. No. 1 Type Uniselector. The uniselector mechanism illustrated in Figs. 76, 77, and 78 was originally designed by The General Electric Company, Limited, and has for some years been the standard unidirectional mechanism of the British Post Office automatic system. The uniselector is of the step-by-step type with a ratchet and pawl system to move the wipers round the bank. The switch is of the reverse-acting type, i.e. the wipers are stepped on the release of the armature. There are two models—one with a capacity of up to 5 rows of bank contacts, and a larger uniselector which provides for up to 8 levels. The 5-level switch is illustrated in Figs. 76 and 77, whilst Fig. 78 gives a general view of a typical 8-level switch. Both types have a 25-contact bank which can be used to give either 25 working outlets, or 24 outlets plus a home position, as desired.

Bank Assembly. The uniselector bank consists of a number of semi-circular rows, each of 25 contacts. The contacts are equally spaced round the bank and are stamped from hard rolled brass, except on heavy-duty switches where the bank contacts are usually of nickel silver instead of brass. In some cases, where homing facilities are required, a solid arc extends over the space normally occupied by 24 of the contacts and a single contact is provided for the home position (see Fig. 77). The bank contacts are insulated from one another by silk impregnated with a high grade insulating varnish, the rows being separated by aluminium spacers pressed between them. These

spacers, in addition to providing mechanical rigidity to the assembly, also act as screens against the effects of electrostatic induction which might produce overhearing. The banks of contacts are assembled between two mild steel frames which are zinc plated and colourless lacquered for protection. The whole assembly is clamped by a number of bolts.

Wiper Assembly. The wipers, which are stamped from hard rolled phosphor bronze sheet, are normally double-ended and are arranged in pairs. The tip of one wiper (when in the bank) makes connexion with one side of the bank contact, and the

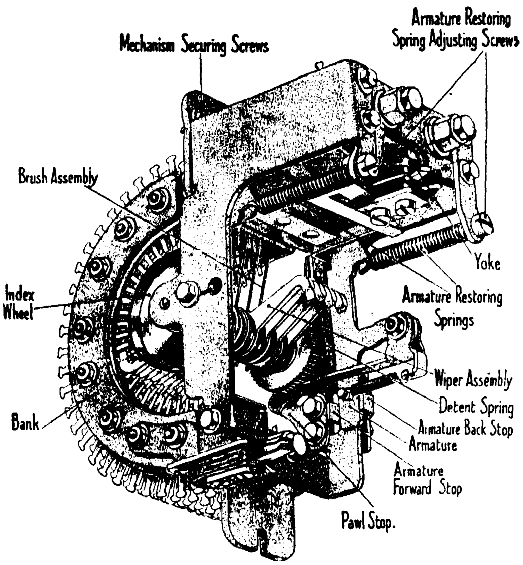


FIG. 78. GENERAL VIEW OF 8-LEVEL UNISELECTOR (No. 1 type)

tip of the other wiper engages with the other side of the same contact. It is sometimes important, from a circuit point of view, that adjacent contacts of the uniselector bank should not be connected together as the wiper passes from one contact to the next. In other circumstances, the circuit arrangements necessitate a wiper which shall maintain continuous contact with the bank as the wiper passes from one contact to another. There are therefore two distinct types of wiper tip known as *non-bridging* and *bridging* wipers (Fig. 79). The two types of wiper blade can be assembled in any desired combination, depending upon the purpose for which the uniselector is to be used.

The wipers are assembled on (and suitably insulated from) a tubular extension of the ratchet wheel. The whole assembly, including a number ring, is then clamped to form a rigid wiper assembly which can be removed from the uniselector as a complete unit. The wiper assembly rotates on a polished steel shaft which is fixed to the side members of the uniselector frame. Although the standard uniselector is essentially a 25-point mechanism, it can be made to behave as a 50-outlet

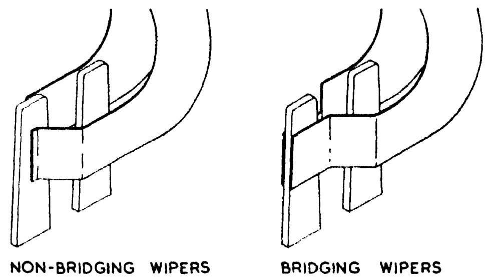


FIG. 79. BRIDGING AND NON-BRIDGING WIPERS

uniselector by the use of single-ended wipers staggered as shown in Fig. 80, and arranged to hunt over alternate rows of contacts during successive half revolutions of the switch. Uniselectors so arranged are often known as *double search* uniselectors.

The wipers are normally tensioned so that they exert a pressure of 30 ± 10 g on the bank contacts. Electrical connexion to the wipers is made by brushes of bronze wire which ride in the collector rings associated with each pair of wipers. The brushes are arranged as part of the bank assembly with the connexion tags adjacent to the bank contacts of the first outlet. It is important that the wire collector brushes should maintain good electrical contact with the rings of the wiper assembly. A tension of 35 ± 10 g (measured at the tip of the brushes) is specified.

Uniselector Mechanism. The essential parts of the uniselector mechanism are shown diagrammatically in Fig. 81. The switch magnet is of the

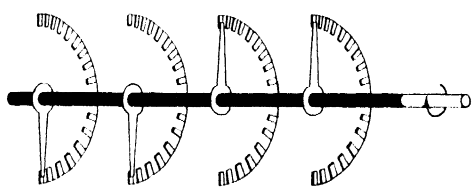


FIG. 80. WIPERS ARRANGED FOR DOUBLE SEARCH

twin coil type with glands for the adjustment of the armature air gap. The armature itself pivots about a knife-edge and, when it is in its normal position, an extension of the armature (the armature lever) rests against the armature back stop. The restoring force on the armature is provided by two helical restoring springs, the tension of

which can be readily adjusted by means of screws which project from the front of the uniselector frame. The steel pawl has a case hardened tip and is riveted to a flat pawl spring which, in turn, is rigidly attached to a horizontal projection of the armature lever. The pawl engages with the under side of the ratchet wheel and the stroke of the armature is so adjusted that the pawl steps from $1\frac{1}{4}$ to $1\frac{1}{3}$ teeth when the armature is operated electrically. A detent of spring steel is fixed to the uniselector frame and engages with the teeth of the ratchet wheel to prevent backward movement of the wiper assembly. There is also a pawl stop which lightly wedges the pawl against the ratchet wheel when the armature restores to normal. This prevents the wiper assembly from over-riding the bank contact at the end of the return stroke of the armature.

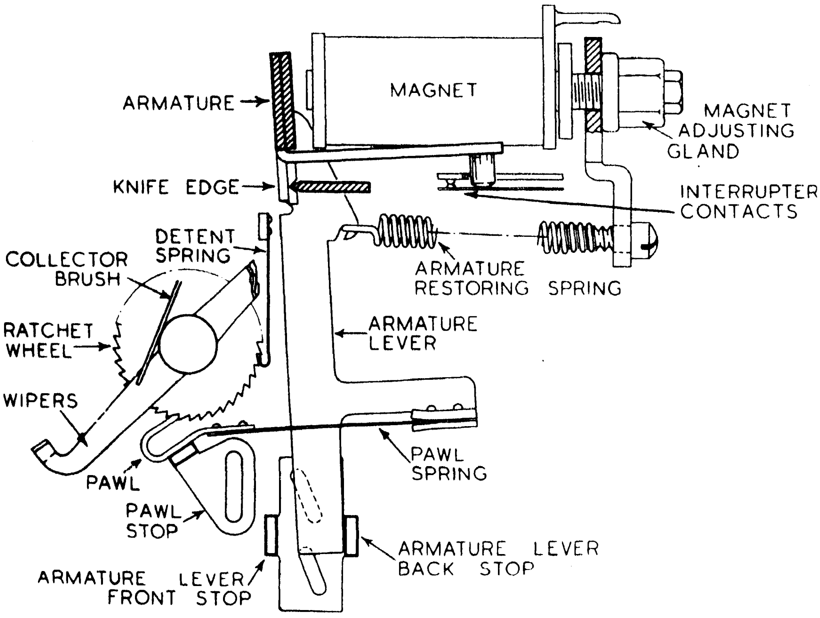


FIG. 81. MECHANICAL ARRANGEMENTS OF UNISELECTOR (Diagrammatic)

The armature lever back stop is first adjusted so that the tips of the non-bridging wipers are flush with the leading edges of the first bank contacts. The detent spring is now adjusted so that it drops into each rotary notch without allowing any appreciable backlash in the wiper assembly. (A detent pressure of 150 ± 50 g is specified.) The armature lever front stop is provided to prevent abnormal forward movement of the pawl, and it must be adjusted so that the pawl cannot drop over the second forward tooth of the ratchet wheel when *the armature lever is operated by hand. A mechanism positioning gland is provided at the lower end of the uniselector frame. This gland is used to* ensure that the wipers occupy the same relative position on the 25th bank contact as they do on bank contact No. 1. The position of the magnet coils must now be adjusted by means of the glands, so that the armature strikes both magnet cores simultaneously and so that the pawl will step between $1\frac{1}{4}$ and $1\frac{1}{3}$ ratchet teeth.

An insulated buffer mounted on an extension of the armature is arranged to open a pair of interrupter springs when the driving magnet is fully energized. These interrupter contacts are necessary in some circuits to provide automatic rotary drive (see Chapter VII), or for other purposes. The point of operation of the interrupter springs can be adjusted by bending the spring operating lever.

Uniselector mechanisms are usually tested for good adjustment by inserting a resistance in series with the magnet windings. A uniselector designed for use on a 50 V exchange is, for example, tested with a 20 Ω resistor in series with the magnet coils. If the switch fails to rotate smoothly under these conditions, it must be re-adjusted, after which it is required to operate satisfactorily through a resistance of 25 Ω. The 5-level mechanism has a speed of the order of 60 to 70 r.p.m., whilst the 8-level uniselector has a somewhat lower speed of 55 to 65 r.p.m.

No. 2 Type Heavy-duty Uniselector. The design of uniselector described in previous paragraphs has been the standard mechanism of the Post Office System for more than fifteen years. During this time a considerable experience was accumulated of the desirable points of uniselector design, and these data have been used in the development (by Messrs. G.E.C.) of a new mechanism for heavy-duty work. A high proportion of the uniselectors employed in a standard automatic exchange can be of a light-duty type, i.e. they are required only for occasional use. A comparatively small number of uniselectors is subject to very heavy usage and must, therefore, be of rugged construction in order to give satisfactory service over a prolonged period. Whilst there

are some advantages in standardizing one design of uniselector, it is clearly not economical to incur additional expense on uniselectors which are required only for light duty in order to meet the occasional demands for a heavy-duty selector. Generally speaking, a light-duty mechanism is magnetic circuit of low reluctance. The large core diameter and the generous dimensions of the coil, coupled with the greater efficiency of the magnetic circuit, provide a suitable reserve of power even under the most adverse conditions. The armature is conveniently mounted on a knife-edge at the

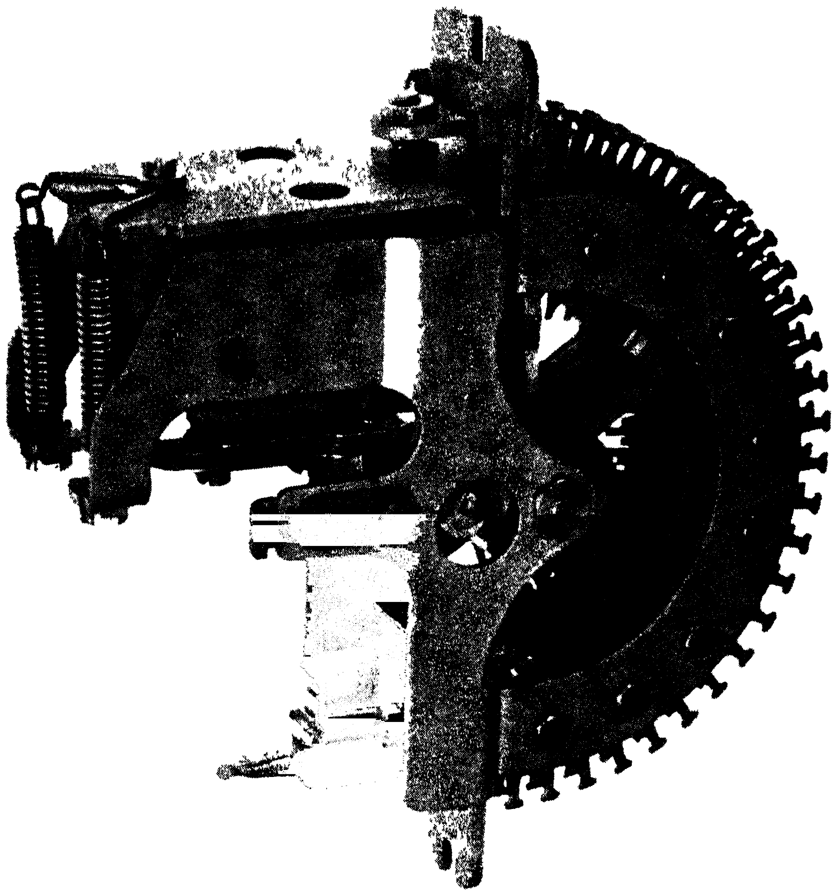


FIG. 82. NO. 2 TYPE HEAVY-DUTY UNISELECTOR (5-LEVEL)

specified where a maximum life of some 25 million steps is satisfactory. When a life in excess of this figure is required, a heavy-duty switch, which is designed to give a life up to about 100 million steps, is employed.

Fig. 82 gives a general view of a 5-level mechanism, whilst Fig. 83 shows the somewhat wider 8-level switch. The new uniselector employs a single coil electromagnet with a large diameter core and a box shaped yoke (Fig. 84). This yoke presents three edges to the armature, thereby producing a front of the magnet assembly (Fig. 85), whilst adjustment is provided by the positioning of the knife-edge itself and the armature back stop, both of which are easily accessible when the uniselector is mounted on a rack. A stainless steel residual plate is fitted to the armature to prevent the complete closure of the magnetic circuit and thereby to make the speed of restoration of the armature uniform under various conditions of operation.

The interrupter contacts (Fig. 86) are mounted on a sub-assembly, the base-plate of which has a

slight camber. By the relative adjustment of the two fixing screws it is possible to change the position of the contact springs relative to the operating mechanism without bending either the springs or the operating detail. Stops or buffers are provided for the fixed spring to minimize vibration and brushes were of phosphor bronze wire which made contact on the cylindrical surface of the collector rings. The brush feeds are between the separate units of the wiper assembly so that the wiper tips do not pass over the brush feeds as in some of the earlier designs where this type of feed is employed.

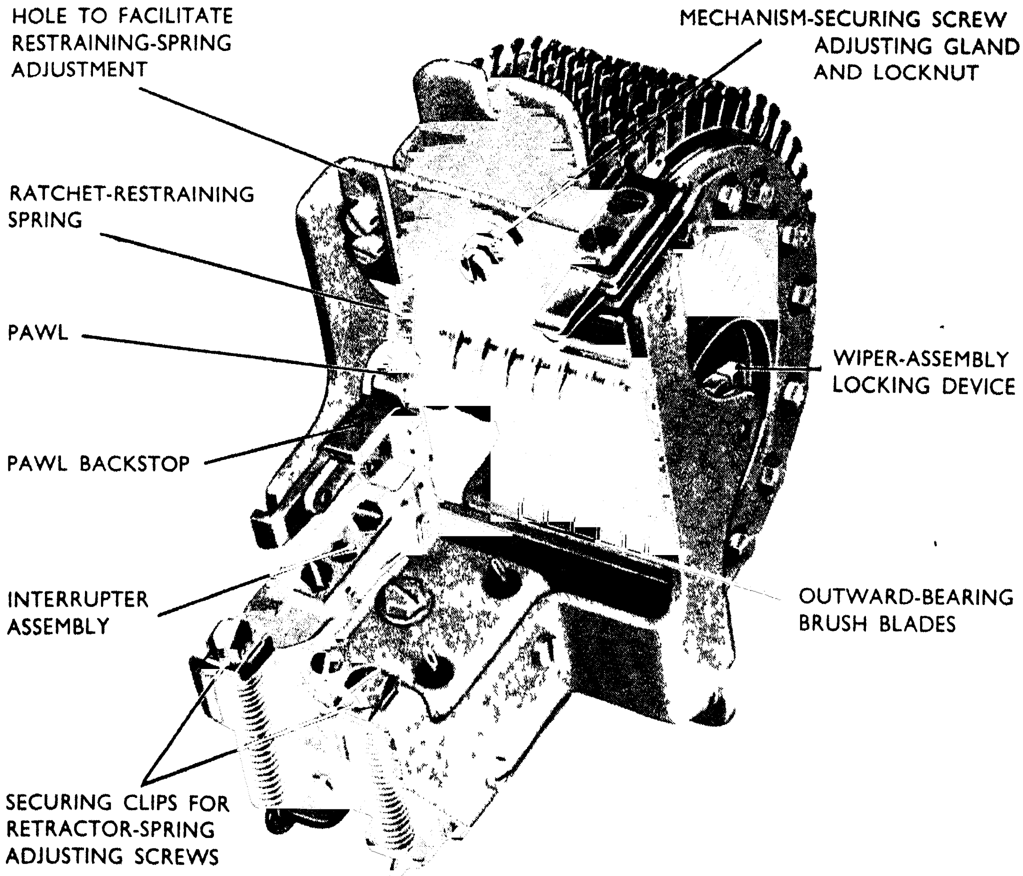


FIG. 83. NO. 2 TYPE HEAVY DUTY UNISELECTOR (8-LEVEL)

contact bounce during operation of the switch. The interrupter contacts themselves are of tungsten to give a long life. The contact springs are operated by an armature extension which passes behind the magnet coil and terminates in a striker made of compressed fabric.

A notable feature of the new design is the use of double nickel silver wiper collector brushes which make contact on the sides of the U-shaped collector rings. This is considered to be an improvement over the previous design where the wiper collector

The ratchet and pawl system has been carefully designed to prevent "pawl throw-out" and the development of backlash during the operational life of the switch (see Fig. 68). The pawl and the ratchet detent are both located at the front of the mechanism so that they can be readily inspected or adjusted.

On the older design the location of the wipers on the bank contacts necessitated a somewhat complex adjustment procedure. On the new switch the wiper assembly has freedom of rotation relative

to the ratchet, with a device for locking the assembly once the adjustment has been made. Thus it is possible to position the wiper tips on the bank contacts without disturbing the adjustment of the driving mechanism. The locking device is located inside the wiper index wheel, and is easily accessible

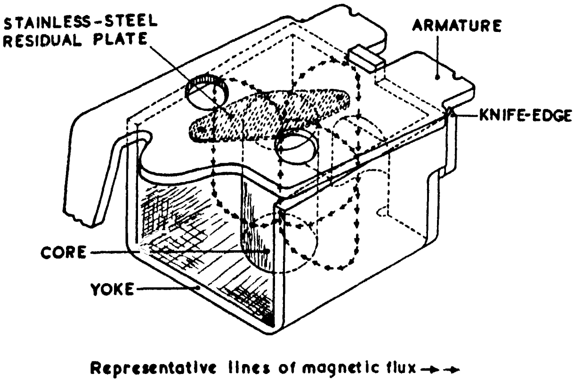


FIG. 84. MAGNETIC CIRCUIT OF UNISELECTOR

for maintenance purposes. After a mechanism has been fitted to the bank, the wiper assembly is unlocked and is then rotated to the correct position before it is again secured.

The wipers (Fig. 87) have flared tips so that the wiper assembly can be rotated backwards or for-

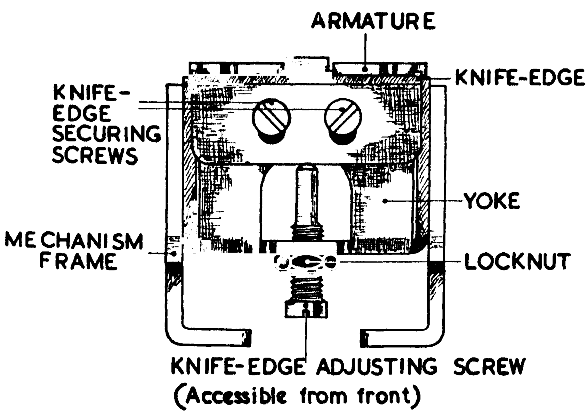


FIG. 85. MOUNTING AND ADJUSTMENT OF ARMATURE

wards during adjustment. On the heavy-duty selector, the wipers, wiper feed brushes, collector rings and the bank contacts are all of nickel silver. The new selector also provides additional refinements such as the provision of securing clips for the armature restoring spring adjustment screws, and a lock nut on the mechanism positioning gland.

A new light-duty uniselector (the P.O. No. 3 type) has been designed on the same general lines as the No. 2 type—but with the omission of a number of the refinements.

The Motor Uniselector. Figs. 88 and 89 give two views of the motor uniselector, which was originally designed by Messrs. Siemens Bros. for their No. 17

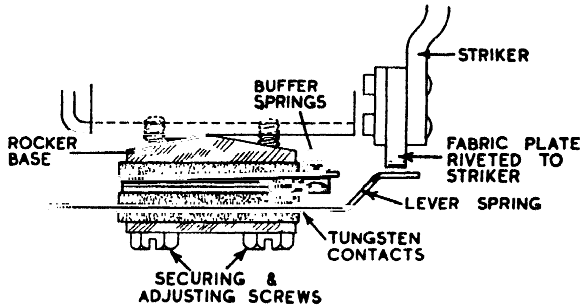


FIG. 86. INTERRUPTER SPRING ASSEMBLY

System. It has now been adopted as standard by the British Post Office for use in special circumstances where a high speed of search and a large bank capacity are required. Unlike the uniselectors

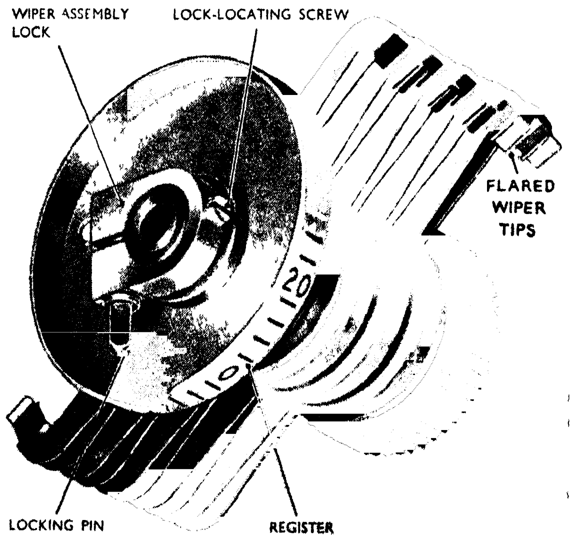


FIG. 87. WIPER ASSEMBLY
(Note flared tips of wiper blades)

already described, the switch is not of the step-by-step type and cannot be stepped directly from dial impulses.

Fig. 90 shows the principle of operation and the mechanical arrangements of the switch. The operation of a start contact of a suitable relay energizes the latch magnet of the selector which, in attracting

its armature, withdraws the toothed latching lever from engagement with the wiper shaft gear wheel. Auxiliary contacts on the latching lever outlet is reached, a high-speed test relay operates and a break contact of this relay disconnects the holding circuit of the latch magnet. The latch now

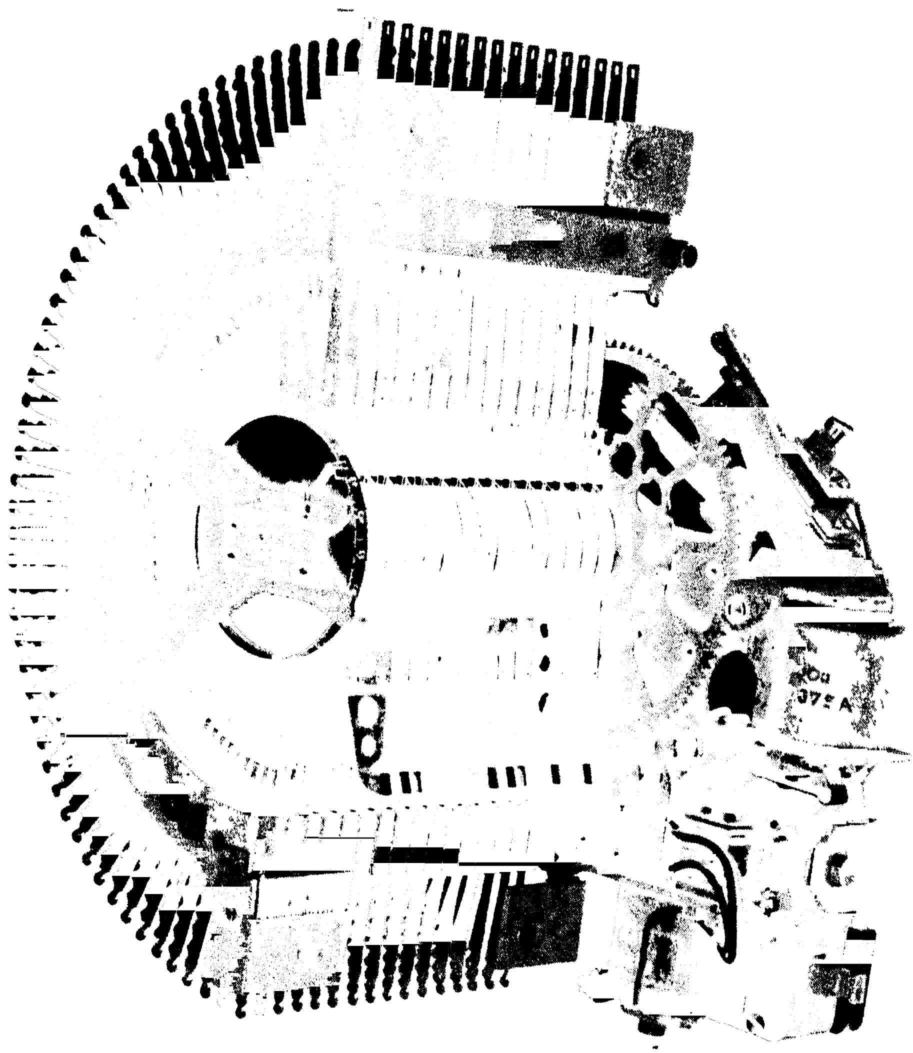


FIG. 88. MOTOR UNISELECTOR
(Wipers off-normal to show feeder springs)

now close to complete the circuit of the motor magnets. The motor now rotates the wipers until such time as the appropriate marking condition is encountered. In Fig. 90 a battery potential is shown as the marking condition. When the required releases, first disconnecting the motor circuit and then mechanically locking with the wiper gear wheel. This mechanical locking of the rotating wiper system may at first sight appear to be rather drastic. It has, however, been found in practice

that the system is mechanically sound and that there is no abnormal wear even after prolonged life tests. This has been achieved to some extent by pressed into the steel gear wheel by a flat spring. The detail is coupled to the latching armature by a pair of bowed arms which provide a

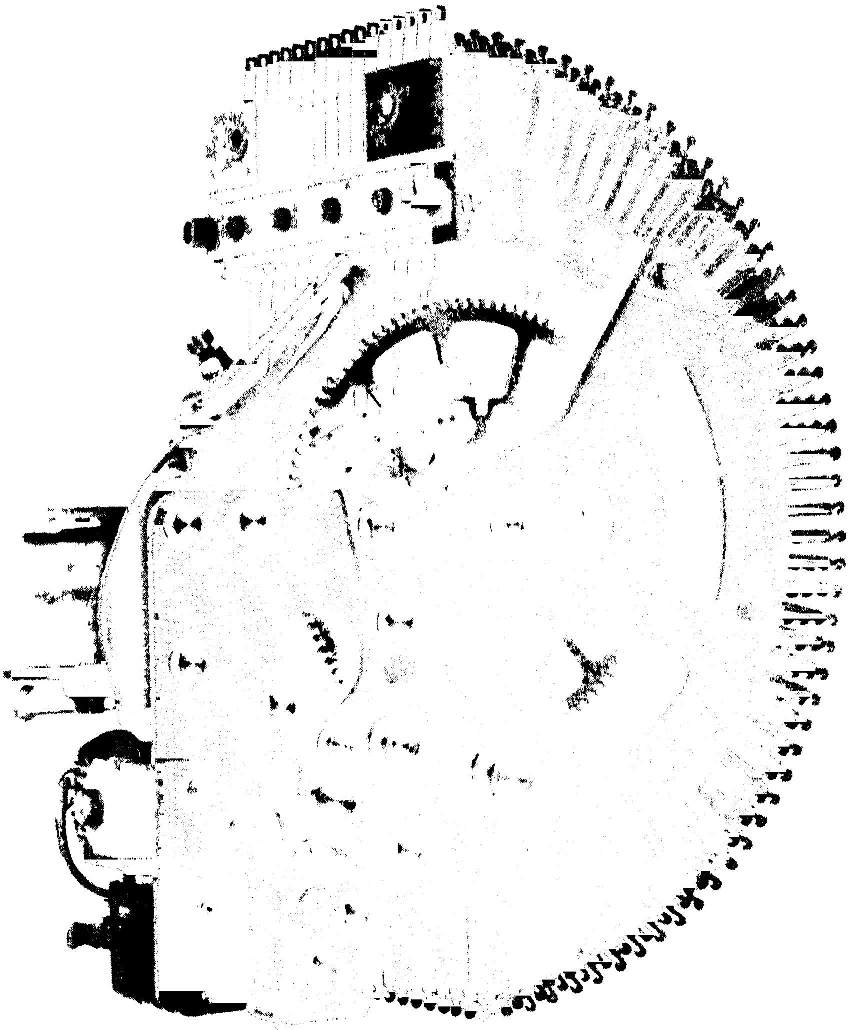


FIG 89. MOTOR UNISELECTOR
(Viewed from right)

making the mass of the rotating parts as small as possible, thereby minimizing the momentum of the system. In addition, the design incorporates certain devices for absorbing the kinetic energy of the moving system at the moment of stopping. The latching detail is of bronze and it is normally longitudinal "give" to absorb the momentum at the instant of stopping. Tendency for the latching detail to bounce on the wiper wheel is overcome by the damping effect of the latch restoring spring.

The adjustment of the latch contact is also of some importance. It is arranged that the contacts

open on release just after the latch teeth enter into engagement with the wiper wheel teeth. If, therefore, the teeth of the latch become placed in crest-to-crest contact with the wiper wheel teeth, the mechanical closure of the latch contacts maintains

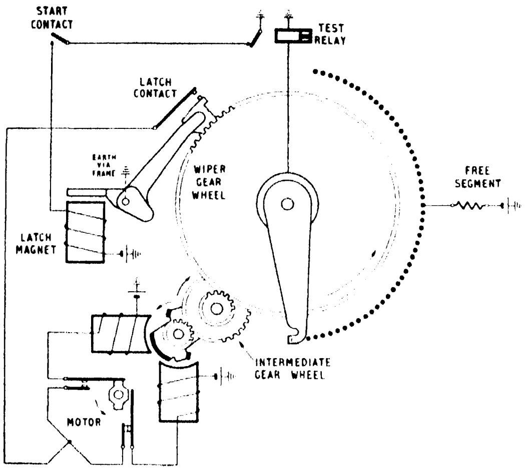


Fig. 90. Mechanical Arrangements of Motor Uniselector

the power to the motor and thereby causes the wipers to move forward slightly until the latch and gear wheel teeth mesh correctly. Homing type switches are provided with off-normal contacts which directly control the latch release.

The Driving Motor. Fig. 91 shows the motor action in somewhat more detail. The armature is symmetrically balanced about its pivot, and has two main poles, No. 3 and No. 5, and two auxiliary poles, 4 and 6. The former present circular faces which match the ends of the curved magnet cores. The auxiliary poles are substantially at right angles to the main poles. All four poles are supported by an iron web through which the spindle passes. Assume that the rotor is in the position shown at "*a*" when movement commences. With the armature in this position the interrupter contacts are so arranged that electromagnet No. 1 is energized so that there is a torque on main pole 3 which produces a clockwise movement of the rotor. When the rotor reaches the position shown at "*b*," the circuit of electromagnet 2 is closed and that of the first electromagnet is broken. With the rotor in this position pole 4 presents its rectangular face squarely to magnet 2 so that a good torque is obtained and rotation continues until the armature reaches the position shown at "*c*." By this time the torque on pole 4 is substantially exhausted and the force is largely an axial pull. The axial force is, however, small due to the fact that pole 4 now presents its edge of comparatively small area to the magnet and this, combined with the relatively large air gap, results in most of the flux passing to pole 3. Torque is thereby still maintained and the armature is further moved to the position shown at "*d*." The interrupter contacts now reverse the connexions to the two magnets so that pole 6 is attracted to magnet 1 and when the position shown at "*a*" is again reached, main pole 3 is approaching magnet 1 and the torque is maintained as explained above.

The rotor has a speed of some 50 revolutions per second and is coupled to the large wiper gear via an intermediate gear of such a ratio that the wipers are moved over the bank at the rate of 200 contacts per second. Due to the high rotor speed the question of lubrication is important. In the motor uniselector the rotor spindle is hollow and encloses a reserve of oil contained in a saturated wick. The idler gear is similarly lubricated.

Wipers and Bank. The wiper assembly consists of 16 single-ended or double-ended wiper blades,

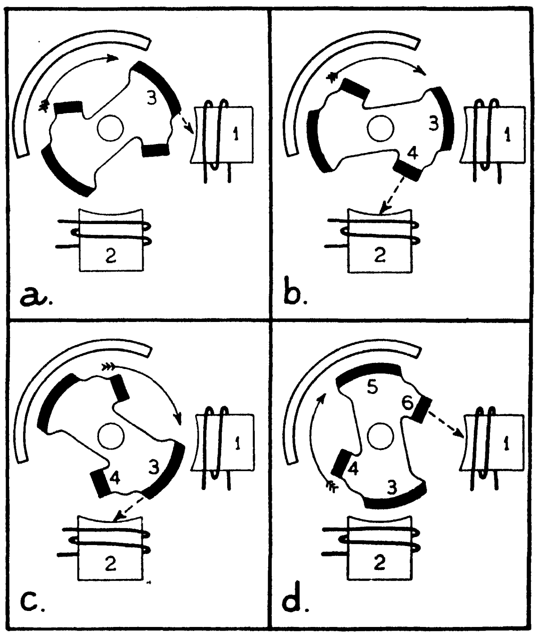


Fig. 91. Principle of Driving Motor

each of which is fitted with a pair of flexible tips for making contact with both sides of the bank contact. The wiper assembly can be made up to give any required arrangement of wipers. The use of single-ended wipers gives facilities for consecutive search over two adjacent groups, each of 51 contacts, whilst, by arranging two such sets of

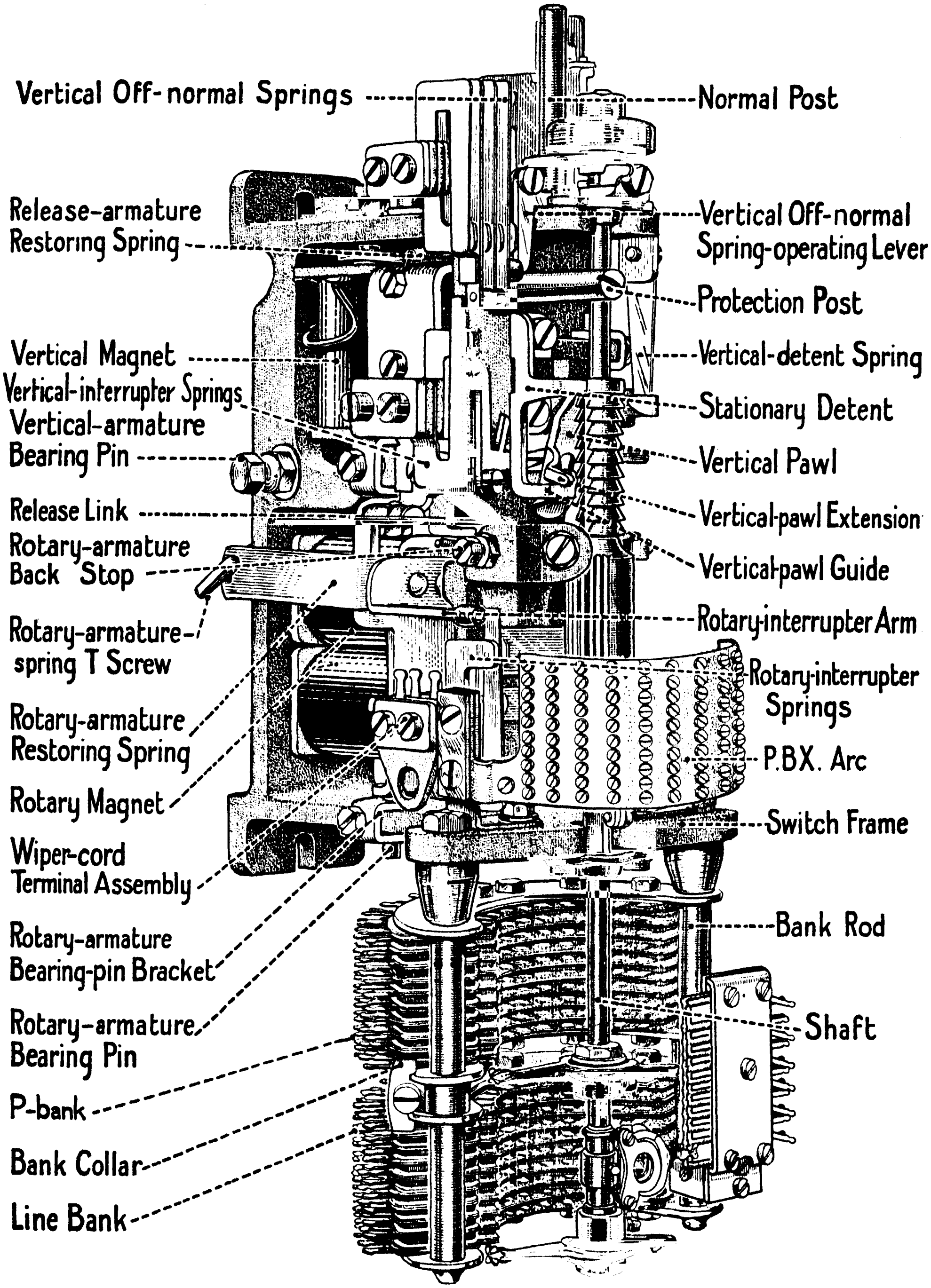


Fig. 92. Pre-2000 Type 2-motion Selector
(Viewed from left)

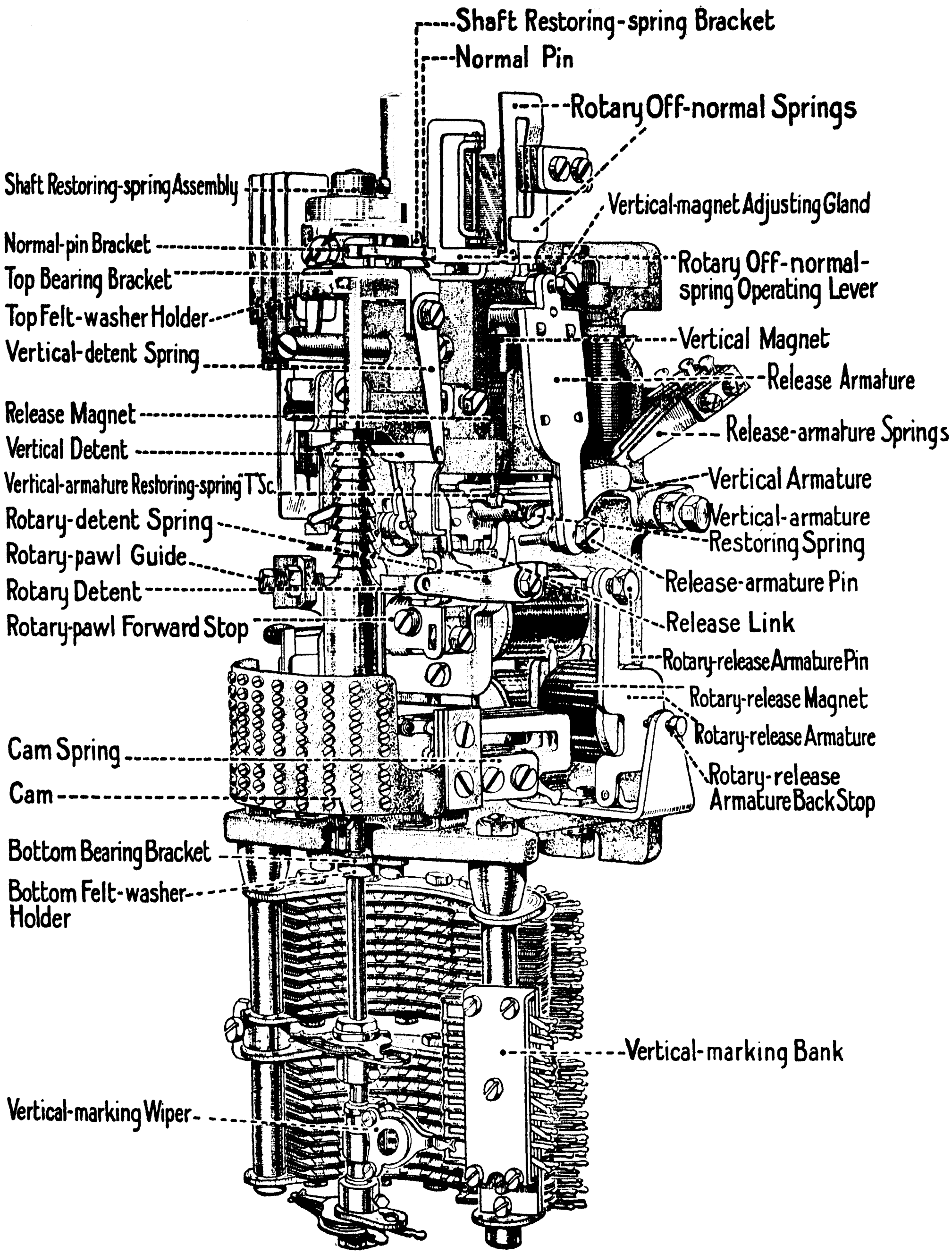


FIG. 93. PRE-2000 TYPE 2-MOTION SELECTOR
(Viewed from right)

wipers in parallel, the circuit can be arranged to give a search over 204 outlets during one complete revolution of the wiper assembly. If, on the other hand, double-ended wipers are provided, the switch gives facilities for up to five separate groups of wipers, each of which serves 51 outlets during one half revolution of the switch. The wiper feed brushes are attached to a sub-assembly of the bank and are in the form of blades fitted with pairs of flexible tips. The tips engage discs on the wiper assembly in such a way that the wipers pass between feeders and not over them. The bank contacts, wipers, and the tips of the wiper feed brushes are of nickel silver.

The connexion tags of the bank assembly are of special design to accommodate a machine-made flat ribbon cable. The cable lies between the extended connexion tags, so that all soldered connexions to the tags are readily accessible for inspection. The flat ribbon cable incorporates a transposition system between each bank for all the speech conductors. This arrangement reduces the liability to cross-talk, and permits the use of larger gradings.

Pre-2000 Type 2-motion Selector. The principle of the 2-motion selector has already been considered briefly in Chapter I. Figs. 92 and 93 give left- and right-hand views of a typical mechanism used extensively prior to the introduction of the Post Office 2000 type selector. The selectors manufactured by different telephone contractors vary slightly in detail, but they are of the same general construction. The selector is of the 3-magnet type, i.e. with vertical, rotary and release magnets. The frame is an iron casting with compartments for the vertical and rotary magnets. The banks are fixed to the lower part of the casting by two bank rods, the bank units being fixed to the rods by collars and clamping screws.

The wiper shaft is of solid steel with the vertical and rotary ratchets arranged vertically one below the other. The shaft bearings are attached to the top and bottom flanges of the casting and lubrication of the shaft is effected by the use of oiled felt washers located in these bearings. It will be noted that the lower (wiper) end of the shaft is free.

Apart from the operating magnets and the associated ratchet and pawl systems, the selector provides for a variety of mechanically operated springs, and there is an auxiliary arc to provide for automatic hunting over the lines of a P.B.X. group. The differences between selectors made by various manufacturers are largely in respect of the mechanically operated springs and auxiliary equipment. The selector illustrated in Figs. 92 and 93 shows most of the subsidiary equipment, mechanically operated springs, etc., which can be associated with a 2-motion selector. In practice it is very rare for any one selector to be provided with all these items.

Vertical Stepping. Fig. 94 shows the vertical magnet and its pawl and ratchet system in more detail. The magnet is of the twin coil type and is fixed to the casting by a securing screw and positioning gland. The armature is hinged at the rear of the casting and terminates in the vertical pawl, an armature restoring spring and pawl spring being provided to maintain the armature and

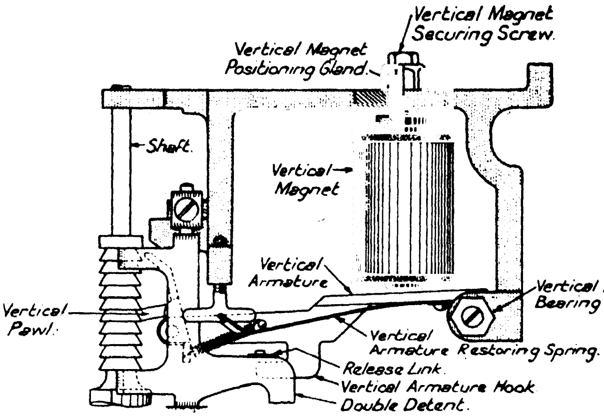


FIG. 94. VERTICAL MAGNET AND ASSOCIATED RATCHET AND PAWL SYSTEM

pawl in the normal position. On receipt of the first impulse, the vertical magnet is energized and the armature is attracted. The vertical pawl engages with the first vertical tooth to lift the shaft to the first level. A pawl guide is provided to ensure that the vertical pawl strikes the root of the tooth during its vertical movement, and similarly an extension of the casting is used as the pawl front stop to avoid overshooting of the shaft at the end of the vertical stroke. A hook-shaped extension of the vertical armature engages with the flat release link spring as the armature is attracted and, as the release link is lifted upwards, the vertical detent is allowed to engage with the vertical ratchet in order to prevent the shaft from falling after each vertical step. The vertical detent remains in engagement with the vertical ratchet throughout the stepping and is not restored until the operation of the release magnet at the end of the call. In Fig. 94 the vertical and rotary detents

are combined as one "double detent." This arrangement is common where a separate rotary release is not required. The rotary part of the detent is not

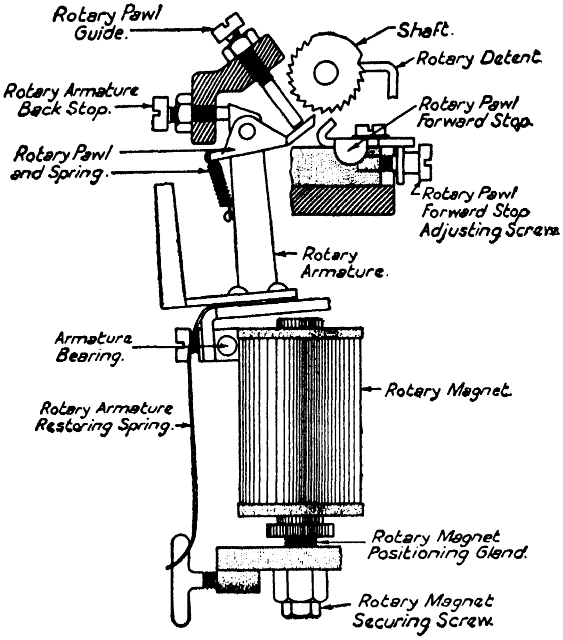


FIG. 95. ROTARY MAGNET AND ASSOCIATED RATCHET AND PAWL SYSTEM

required at this stage and slides in the first tooth of the rotary ratchet during vertical stepping.

Rotary Stepping. At the completion of the vertical stepping, the circuit is switched to the rotary magnet, which is also of the twin coil type. The rotary pawl and ratchet system is illustrated in Fig. 95. As with the vertical magnet, a rotary pawl guide ensures that the rotary pawl shall strike the root of the tooth, whilst a rotary pawl front stop locks the pawl into the ratchet at the end of the rotary armature stroke. In addition to the movable vertical and rotary detents, a stationary detent is provided on the opposite side of the vertical ratchet (see Fig. 92). During vertical stepping this stationary detent slides in a vertical groove in the ratchet and does not in any way support the shaft. At the first rotary step, however, the stationary detent moves into the appropriate vertical ratchet tooth to take over the function of the vertical detent. This is necessary, firstly, to relieve the vertical detent of the weight of the wiper shaft and secondly, where double detents are employed to allow the rotary detent to step over each tooth without releasing the vertical part of the detent.

The adjustments of the vertical detent and of the stationary detent must be accurate. The stationary detent is so adjusted that it is some 3 mils (0·003 in.) below the horizontal face of the vertical ratchet at the end of the vertical stepping. Each tooth of the vertical ratchet is notched to give a downward projection of several mils at the point where the vertical detent rides during vertical stepping (Fig. 96). During the first rotary step the shaft rides off this projecting notch and is lowered slightly on to the stationary detent. The adjustments are such that at the end of the first rotary step the whole of the shaft weight is carried by the stationary detent and the vertical detent is several mils clear of the horizontal face of the vertical ratchet.

Release. During vertical stepping the wiper shaft is held in position after each step by the top limb of the double detent. When the wipers move into the bank, the stationary detent relieves the upper portion of the double detent of the weight of the shaft, and permits the lower part of the detent to engage with the rotary ratchet. Thus, during conversation, the selector is prevented from restoring in a rotary direction by the lower part of

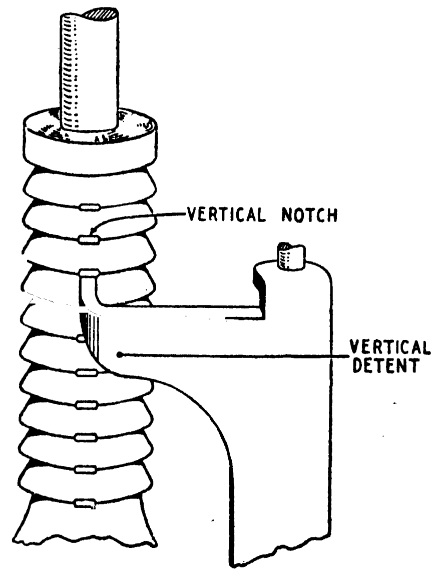


FIG. 96. SHOWING VERTICAL DETENT RIDING ON NOTCH PRIOR TO ROTARY STEPPING

the double detent, and from falling to the normal level by the position of the stationary detent in the vertical ratchet tooth. At the end of the conversation the double detent must be withdrawn from engagement with the shaft to permit first rotary release and, when the stationary detent

reaches the groove in the vertical ratchet, to permit the selector to restore vertically. Fig. 97 shows the arrangement of the release magnet which is energized at the end of the call. Operation of the release magnet armature causes a release pin to engage with the back of the double detent and to depress it to such an extent that the release link falls over the projecting lug of the detent. Once the release magnet has operated, the release link locks the double detent out of engagement with

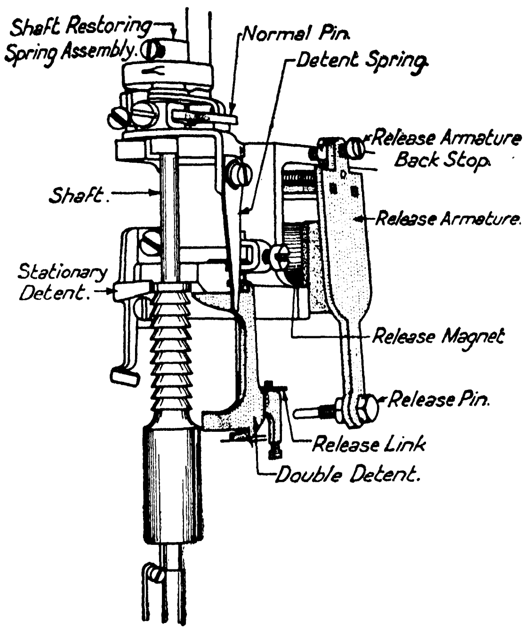


FIG. 97. RELEASE MECHANISM

the wiper shaft—irrespective of whether or not the release magnet is de-energized before the selector comes to normal.

It is sometimes necessary to arrange that the rotary movement only shall be capable of restoration whilst the wipers are retained in their vertical position by the vertical detent. This facility is provided by the use of separate rotary and vertical detents as shown in Fig. 98. The rotary detent is controlled by a separate rotary release magnet, and the operation of the magnet allows the wipers to restore to the normal rotary position. At this point the vertical detent carries the weight of the shaft to prevent vertical restoration. It is now possible to step the wipers to a higher level and to provide rotary search over this new level. At the end of the call, the energization of the main release magnet withdraws the vertical detent from engagement with the ratchet teeth, and the vertical detent in turn strikes a projecting lug of the rotary detent so that the shaft can now restore to normal. As before, a release link is provided to hold both

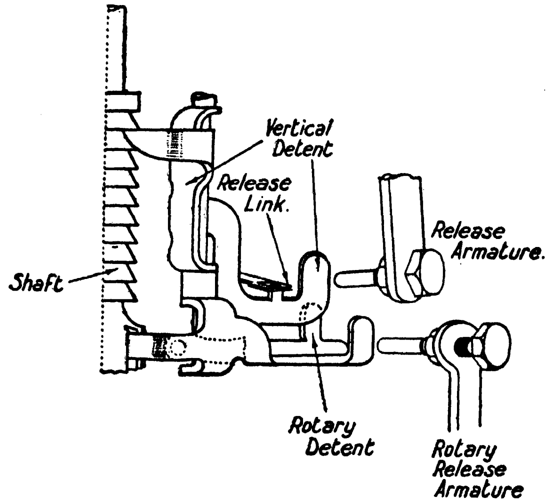


FIG. 98. SEPARATE VERTICAL AND ROTARY RELEASE

detents clear of the wiper shaft once they have been withdrawn.

Mechanically Operated Spring Sets. Modern circuit design requires a large number of contact springs to be operated at various stages during the selector movement. The vertical off-normal springs

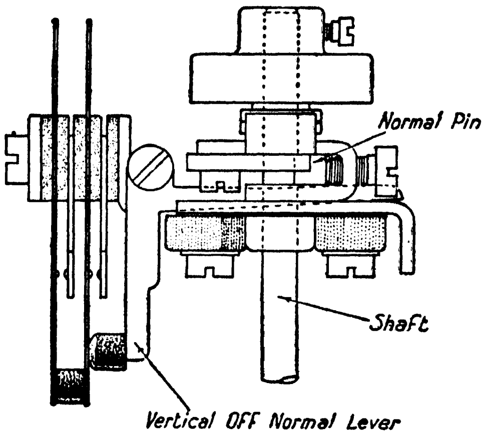


FIG. 99. ARRANGEMENT OF OFF-NORMAL CONTACTS

are fitted to nearly all mechanisms and are arranged to operate whenever the selector shaft is off-normal. Fig. 99 shows a typical arrangement of these springs. The contact unit is fixed at the top of the selector frame and has a bell crank lever which is normally held down by the weight of the wiper

shaft. As the shaft steps vertically, the springs move over due to the removal of the weight of the shaft and are restored only at the end of vertical release.

In some circuits, especially where automatic vertical or rotary drive is required, vertical and rotary magnet springs are provided. These springs are operated by an extension of the appropriate magnet armature and may be either of the make, break, or changeover type. Similarly, contact springs are often provided on the release magnet in order to perform certain circuit functions whilst the release magnet is energized (Fig. 100).

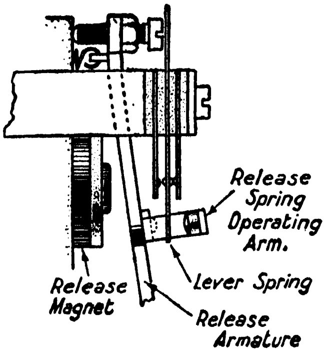


FIG. 100. RELEASE MAGNET CONTACTS

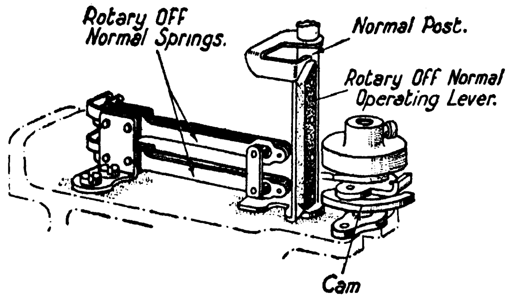


FIG. 102. ROTARY OFF-NORMAL CONTACTS

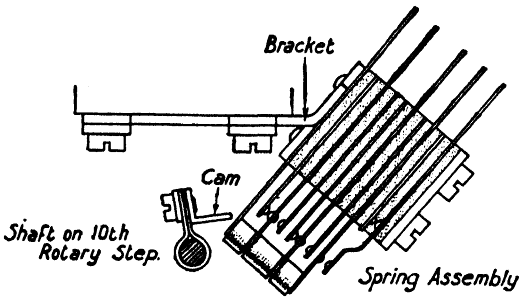


FIG. 101. 11TH STEP CAM SPRINGS

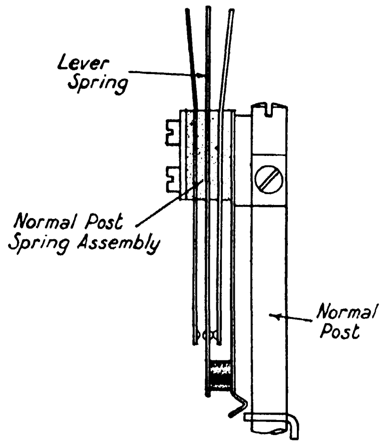


FIG. 103. NORMAL POST SPRINGS

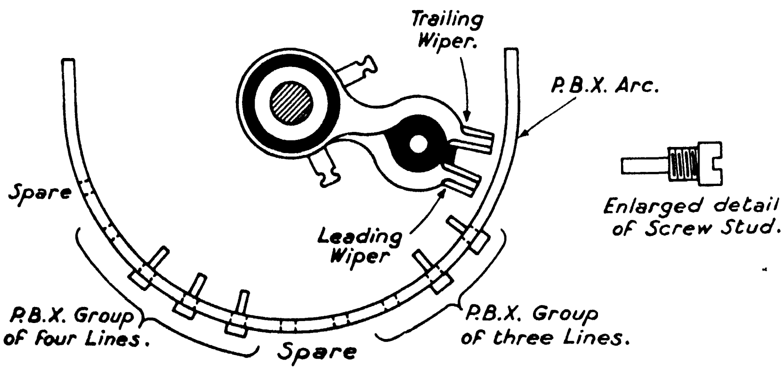


FIG. 104. AUXILIARY ARC AND WIPERS

Most selector circuits require contacts which are operated when the wipers are stepped to the 11th rotary position. These 11th step springs are normally operated from a cam fixed to the wiper shaft (Fig. 101). In some circuits rotary off-normal springs are also required. These springs, as their name indicates, are required to operate at the first rotary step and to remain operated until the end of the rotary release. Fig. 102 shows a typical method of operating rotary off-normal springs from

a cam located immediately below the shaft restoring spring.

Occasionally normal post springs are provided to operate when the selector is stepped to some specific level. Fig. 103 shows an arrangement of normal post springs which are operated by the bracket attached to the shaft restoring spring. The vertical marking bank (see Figs. 92 and 93) fulfils a similar purpose but gives facilities for marking any or all of the ten vertical levels.

Auxiliary Arc. In some cases final selectors are required to hunt over all the lines serving one P.B.X. before busy tone is returned to the calling subscriber. This necessitates a system of rotary self-drive, the limits of which are determined by the size of the P.B.X. group. In the pre-2000 type selector P.B.X. hunting is controlled from an auxiliary arc (Fig. 104) which is often mounted immediately above the lower wiper shaft bearing (see Figs. 92 and 93). The arc is a solid piece of brass in which tapped holes are provided for each vertical and each rotary position. Screws are inserted in this arc in all except the last line of each P.B.X. group. The associated wiper is of a special double type with a leading and a trailing contact arm. The circuit is arranged so that automatic hunting starts when the leading wiper first encounters a screw and is stopped when the trailing wiper, but not the leading wiper, is in engagement with auxiliary arc screws.

Mounting of Relays. The 2 motion selector mechanism is bolted to a pressed steel mounting plate which is provided with bayonet type lugs for fixing to a channel type shelf also of pressed steel. The upper part of the mounting plate is punched to accommodate the controlling relays. Various other components, such as resistors, can also be mounted on the face of the plate in any vacant relay positions. Fig. 105 shows a typical final selector equipped with Strowger type relays. The relays and the mechanism are normally enclosed by a sheet metal cover which is also provided with bayonet lugs to grip on to the shelf channel. The entry of dust is minimized by a strip of felt at the point where the cover and the base-plate of the selector meet.

Fig. 106 shows a semi-rear view of a somewhat smaller selector. The rear of the mounting plate is enclosed by a box designed specially for the accommodation of capacitors. Normally this box is in a vertical position and serves as a dust cover for the wiring. It is, however, hinged at its lower end so that it can be swung out of position for inspection purposes. The external leads from the selector wiring are taken to a plug fixed near the top rear of the mounting plate (Fig. 106). This plug engages with a special jack mounted on top of the channel type shelf.

2000 Type Selector. Until the year 1936 the various telephone manufacturing companies produced 2-motion selectors of the same general

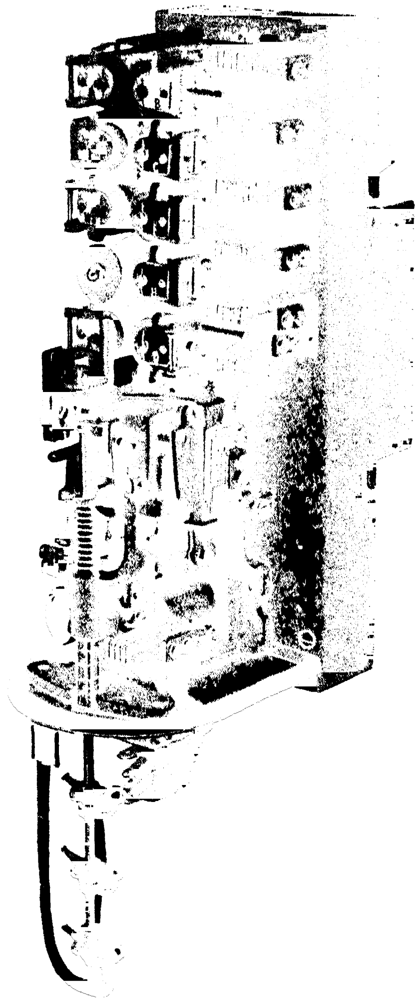


FIG. 105. TYPICAL PRE-2000 TYPE SELECTOR COMPLETE WITH RELAYS

design but with various minor differences which prevented full interchangeability of parts. Moreover, the selector at that time was based upon a design, fixed in the early days of automatic telephony, to which had been added numerous facilities which were not intended originally and which

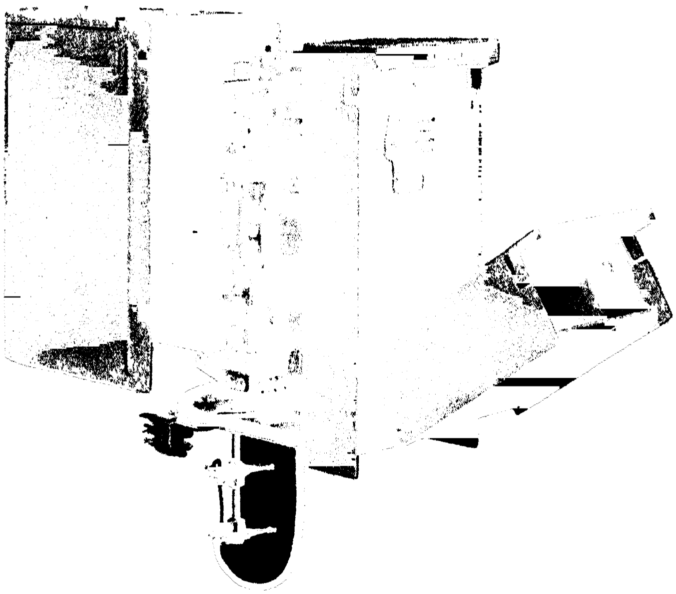


Fig. 106. Rear View of Pre-2000 Type Selector
(Showing capacitor box swung out of position to expose wiring)

produced a complex and cumbersome mechanism. After obtaining a very considerable field of experience of the various features of design, the Post Office decided in 1936 to introduce a standard 2-motion selector which would be more suited to modern switching requirements and which would give full interchangeability of components manufactured by different contractors The new mechanism has become known as the "2000 type" and the older product is now often designated the "pre-2000 type" selector.

Apart from the obvious merits of a uniform design, the 2000 type selector has a number of new and original features. The main changes are:

(a) The vertical restoration of wiper carriage is spring controlled.

(b) Bearings are provided at both ends of the wiper carriage.

(c) The bank capacity has been greatly increased.

(d) There is no separate release magnet

(e) The vertical and rotary magnets are of improved design.

(f) Toggle type interrupter contacts are provided for self-drive circuits.

(g) The auxiliary screw arc has been abandoned.

(h) A selector can be removed from the shelf without disturbing the banks.

(i) There is a reduction of some 30 per cent in the number of piece parts.

(j) The selector is some 30 per cent smaller and lighter.

(k) All mechanically operated springs are concentrated together in an accessible position.

(l) The spring sets and wipers are designed specially to avoid contact bounce.

Fig. 107 shows a 200-outlet group selector of the 2000 type compared with a similar selector of the earlier design. The considerable reduction in size is clear. The weight has also been very materially reduced by the utilization of a die-cast selector frame of aluminium alloy. The new frame weighs about 10 oz as compared with the 2 lb or so of the earlier sand-cast iron frame. The smaller size and reduced weight permit of more equipment being mounted on the apparatus racks, which in turn enables

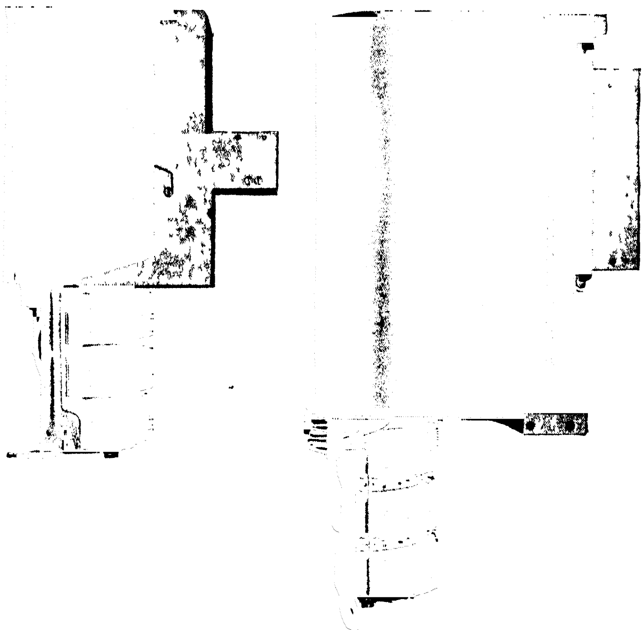


Fig. 107. Comparative Sizes of 2000 Type and Pre-2000 Type Selectors

savings to be made in the building costs of an automatic telephone exchange. Particular attention has been paid in the design of the new selector to simplify and reduce the number of piece parts.

General Arrangements. The general arrangements of the new selector are shown in Figs. 108 and 109, which give two views of a 2000 type line-finder. The numbers refer to the various components as follows:

1. Rotary off-normal springs.
2. Vertical off-normal springs lever.
3. Vertical interrupter springs lever.
4. Guide shaft.
5. Rotary detent.
6. Vertical detent.
7. Vertical ratchet.
8. Vertical off-normal springs.
9. Level springs.
10. Rotary interrupter springs.
11. Level springs lever assembly.
12. Rotary armature.
13. Rotary armature restoring spring.
14. Rotary armature spring tension adjustment.
15. Level springs operating cam.
16. Rotary armature back stop.
17. Rotary detent restoring spring.
18. Vertical detent restoring spring.
19. Rotary ratchet.
20. Wiper carriage tube.
21. Vertical wiper.
22. Wiper clamp.
23. Vertical interrupter springs.
24. Vertical magnet.
25. Vertical armature.
26. Test "U" link.
27. Test jack.
28. Guide shaft.
29. Rotary off-normal springs lever roller.
30. Comb.
31. Rotary pawl guide.
32. Vertical pawl spring.
33. Rotary detent adjusting screw.
34. Rotary pawl front stop locking screw.
35. Rotary pawl front stop.
36. Vertical detent adjusting screw.
37. Lamp jack.
38. Shaft-clamp securing screw.

Fig. 110 shows a semi-plan view of a selector with the relay mounting plate removed and illustrates more clearly a number of parts not readily visible in Figs. 108 and 109.

Vertical and Rotary Stepping. Fig. 111 shows diagrammatically the various pawls, detents, etc., which control the vertical and rotary movements of the wipers. The wiper carriage (C) is a tubular structure with integral ratchets and cams. The mass of the whole moving system is considerably less than the pre-2000 type selector. The wiper carriage slides and rotates on a rigid steel guide rod which is fixed at its two extremities to the frame of the selector. This arrangement avoids the difficulties previously experienced due to "whip" of the free lower end of the wiper shaft. The carriage restoring spring (G) is of the helical type and is inserted between the fixed guide rod and the hollow wiper carriage. The spring is extended as the wiper carriage is stepped vertically and is further tensioned during the rotary movement. It therefore controls not only the rotary restoration of the carriage but also provides the vertical restoring force. Adjustment of the spring tension is effected by slackening a single locking screw. As a result of the above changes, the bank capacity of the 2000 type mechanism has been greatly increased. It is claimed that the standard mechanism can be loaded with up to 10 contact banks as compared with the generally accepted maximum of 3 banks for selectors of the pre-2000 type. Such large banks have not, however, been used in this country.

The hard steel vertical ratchet (A) is in alignment with the vertical pawl (B) only when the wiper carriage is in the normal rotary position. The rotary pawl (D) and detent (E) do not come into alignment with the rotary teeth (F) until the carriage has made one vertical step. When the vertical magnet is pulsed, the wiper carriage is stepped vertically to the level corresponding to the number of impulses received. During vertical stepping the helical restoring spring is extended, and, as the carriage moves from normal, the rotary pawl and detent come into alignment with the teeth of the rotary hub. The rotary magnet is next operated, and the action of the rotary pawl on the rotary teeth moves the wiper carriage round, and in so doing winds up the helical restoring spring. During the first rotary step the vertical ratchet moves out of engagement with the vertical pawl and detent. It is necessary, therefore, to replace the detent by some other means to prevent the shaft from falling. This is effected by the entry of part (J) of the periphery of the disc (O) into a notch in the comb plate (K). The wipers are thus held in position during conversation by the tooth of the comb and the rotary detent. The leading edge of the rotary disc is chamfered so that there is no danger of this disc fouling the comb at the first rotary step (Fig. 115).

The circuit is arranged so that, on release, the carriage is stepped by the rotary magnet to the 12th rotary step. In this position, a notch (L) in the disc periphery comes into line with the comb

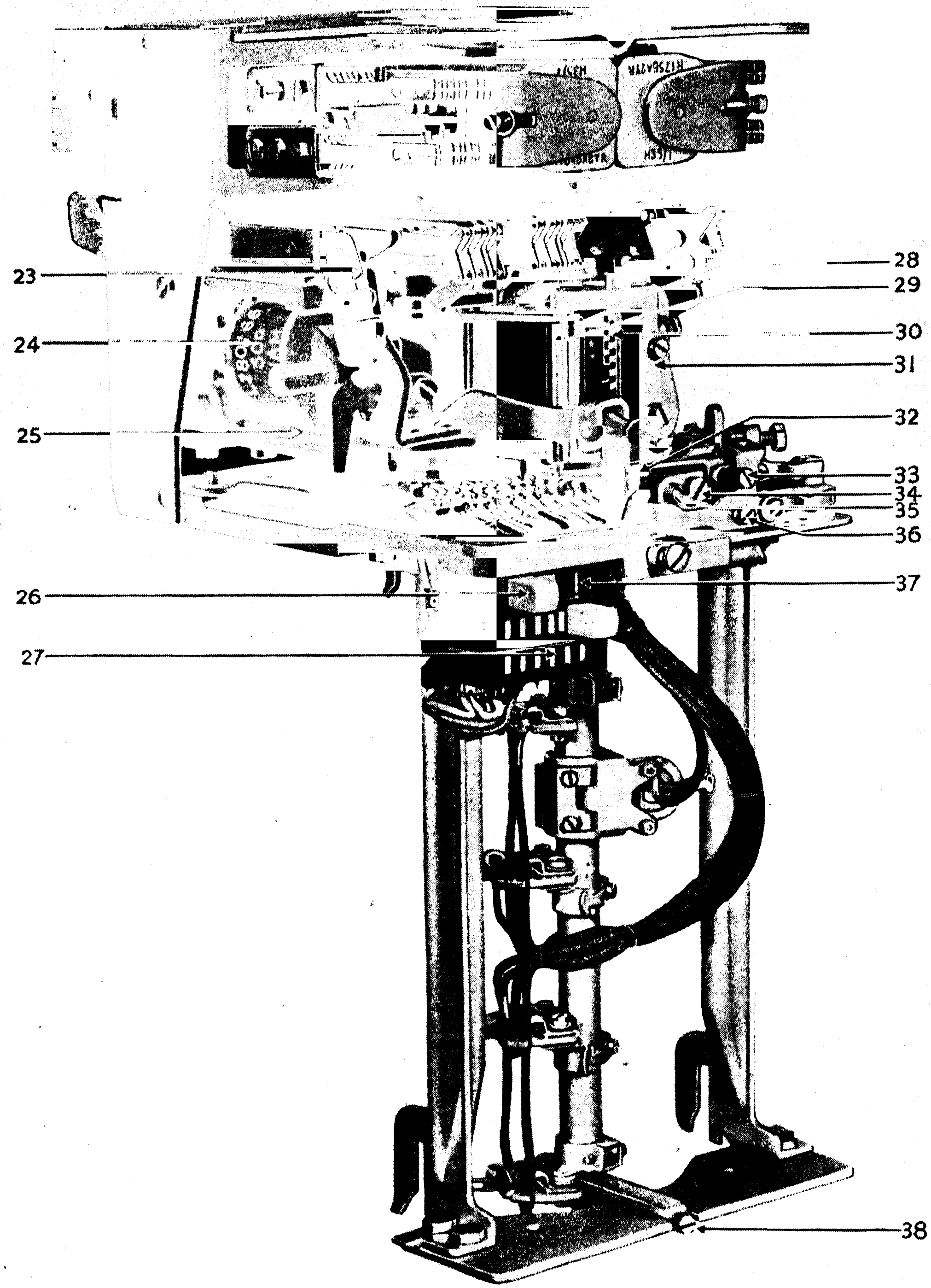


FIG. 108. 2000 TYPE SELECTOR
(Viewed from left)

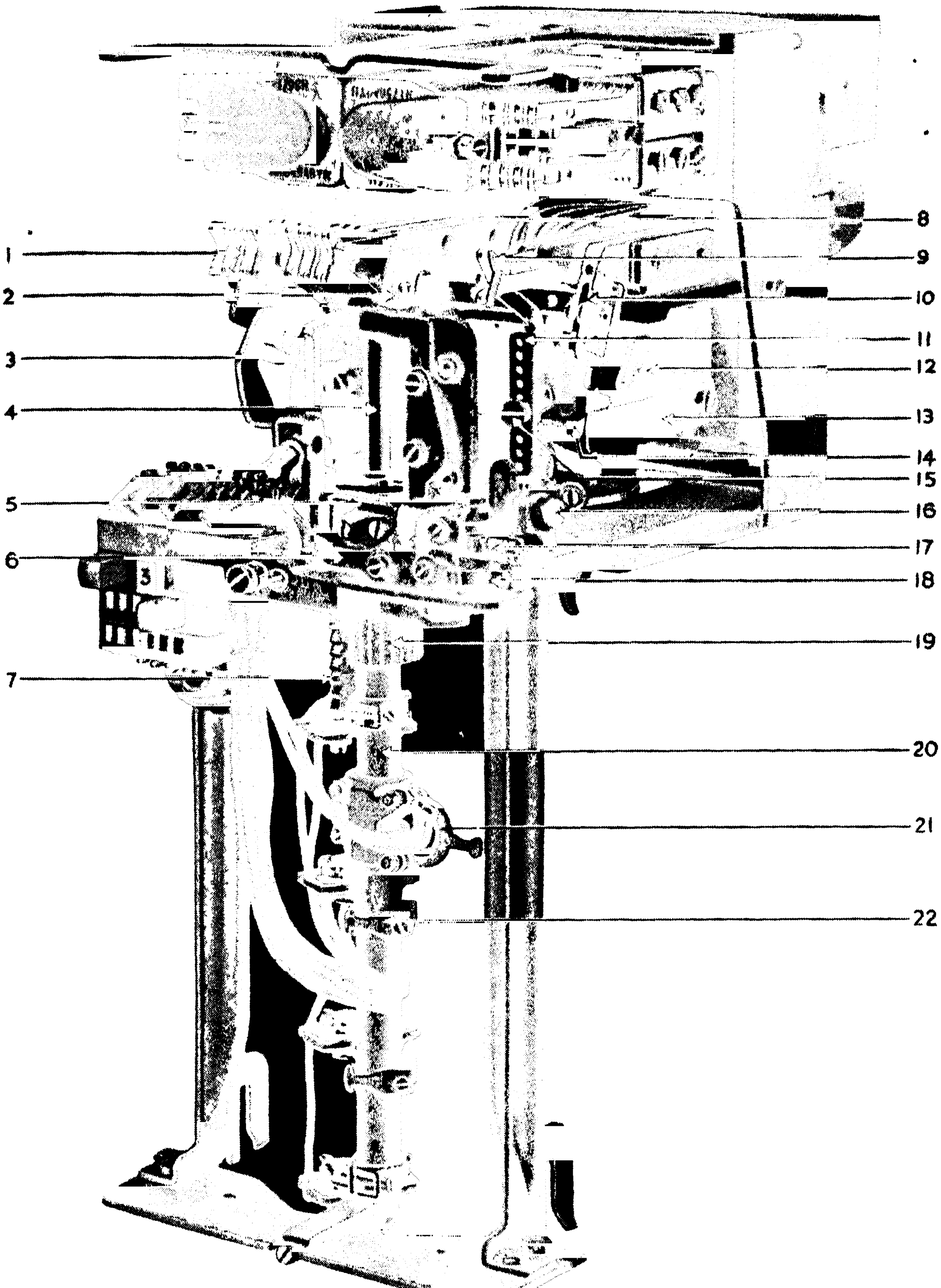


FIG 109. 2000 TYPE SELECTOR
(Viewed from right)

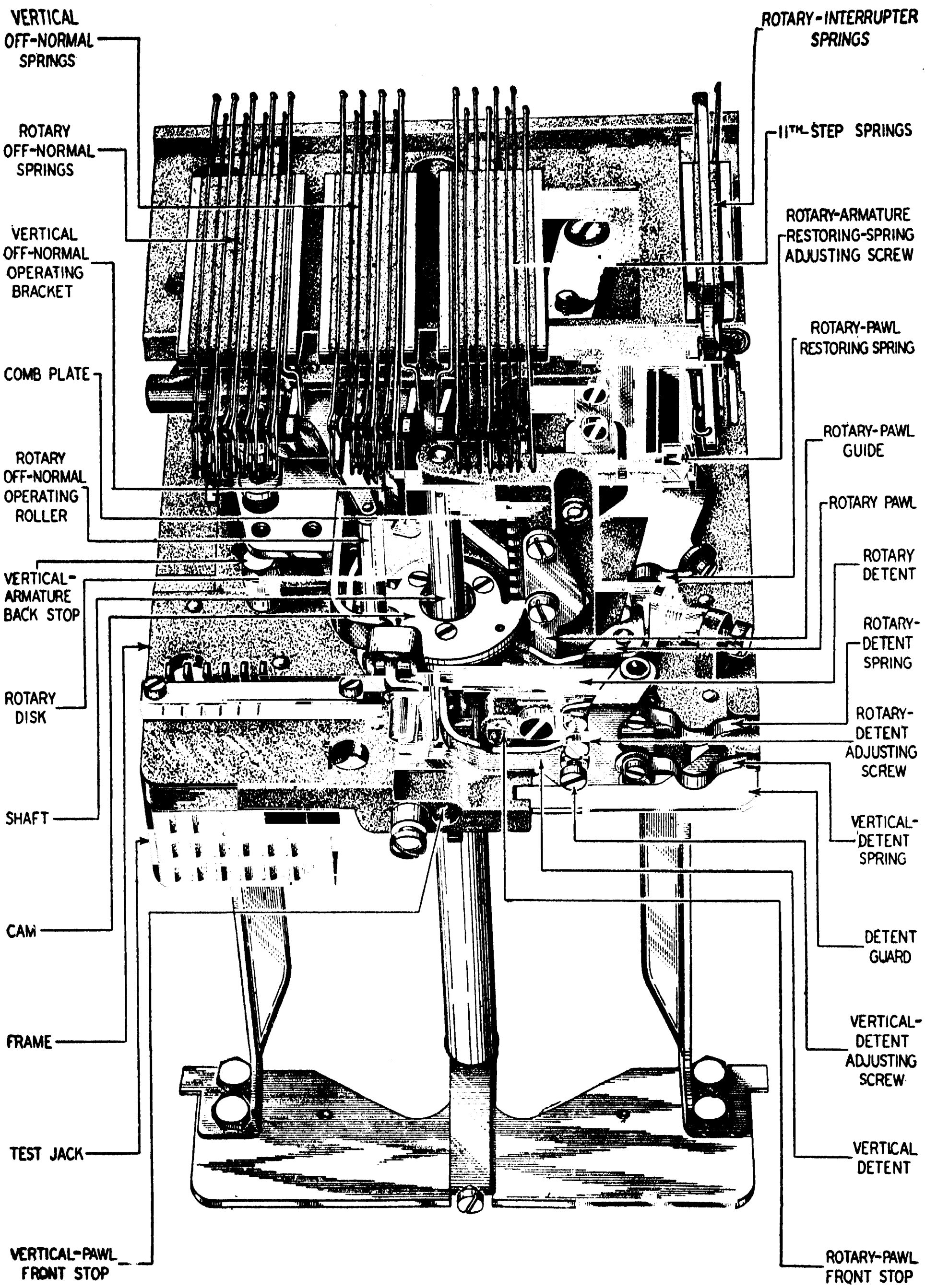


Fig. 110. Semi-plan View of 2000 Type Selector

plate, and the whole wiper carriage is then free to fall under the tension of the spring until arrested by the shaft clamp. Whilst the carriage is falling, the 12th tooth of the rotary ratchet slides along the rotary detent and finally disengages itself when the carriage reaches the normal level. At this point, the rotary restoring force of the spring is free to act and the wiper carriage rotates back to normal. The rotary detent is provided with a projection which latches with the rotary disc on release to hold the wiper carriage in its normal rotary position. This helps to prevent rebound and also prohibits

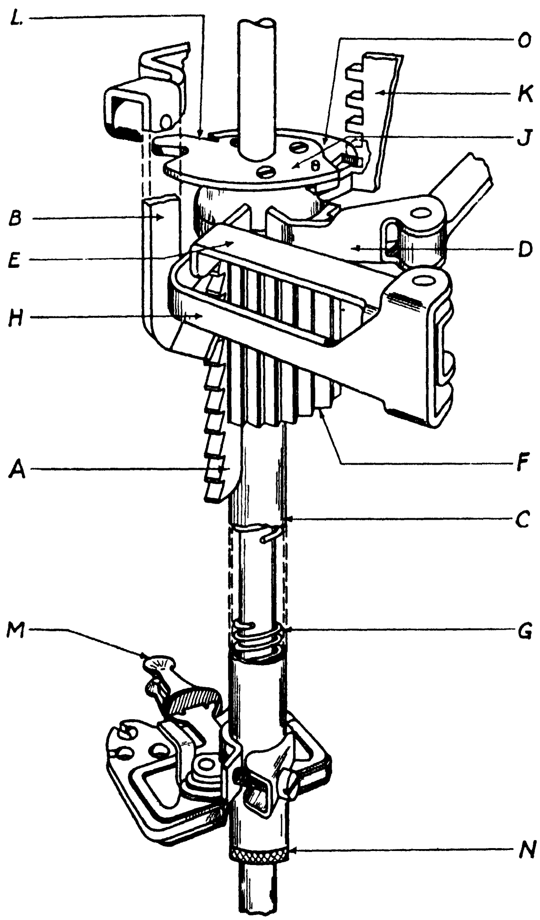


FIG. 111. RATCHET AND PAWL SYSTEM OF 2000 TYPE SELECTOR

rotary movement until the switch is first stepped vertically.

It is a feature of the design that, apart from the off-normal springs, no contact springs are under tension during the falling and reverse rotation period. Consequently no retarding forces are applied to the wiper carriage during release and a lightly tensioned restoring spring can be employed. The off-normal springs impose a load on the wiper

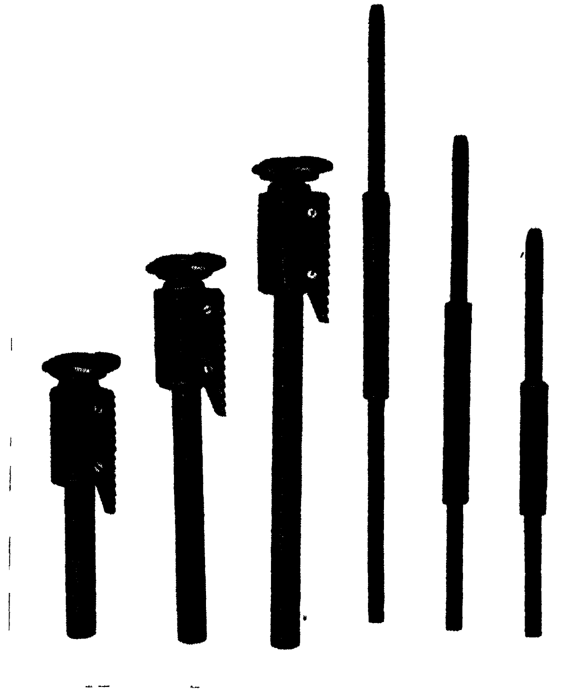


FIG. 112. THREE SIZES OF WIPER CARRIAGE AND GUIDE RODS

carriage at the very end of the release movement. This applies a braking action at the moment the carriage movement is arrested thereby relieving the shock of impact with the stop.

Shaft and Wiper Carriage Assembly. Fig. 112 shows the construction of the wiper carriage and the selector shaft or guide rod. These components are available in several different sizes to suit the bank capacity of the selector. The wiper carriage consists of a brass tube to which is soldered a drop-stamped hub of bronze. The rotary ratchet teeth are cut on this hub which is hollowed for lightness. Considerable research was done in connexion with the design of the ratchet teeth to ensure long life and to prevent pawl throw-out during operation. The vertical ratchet is of case-hardened and tempered carbon steel and is fixed to the hub by means of two screws. A very substantial upper bearing for the wiper carriage is provided by the bronze hub, whilst a replaceable bronze bush at the lower end of the carriage tube forms the bottom bearing.

The weight of the complete carriage (including wipers) in a 3-bank selector is approximately 80 g as compared with some 150 g for the shaft and wipers of the pre-2000 type selector.

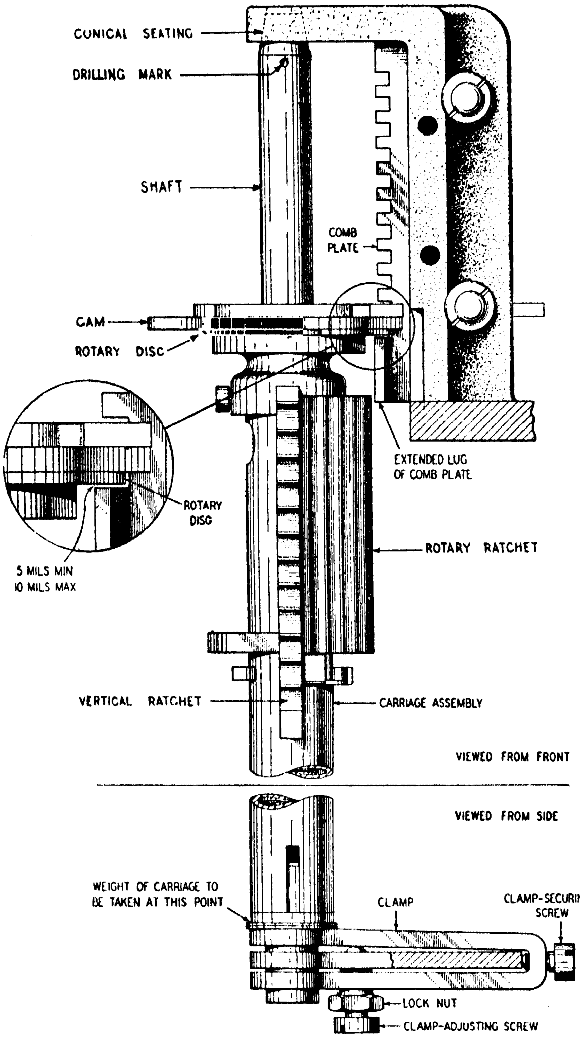


FIG. 113. WIPER CARRIAGE, SHAFT AND CLAMP

The guide rod is of stainless steel tapered at the upper end to engage with a conical seating in the selector frame. At the lower end the shaft is secured to the bottom bridge plate by a U-shaped clamp which is tightened by a single securing screw. The ends of the helical restoring spring are soldered to brass bushes which have radiused shoulders to prevent an abrupt change of diameter when the spring is wound up. The lower bush is pinned to the main shaft, whilst the upper end of the spring *is free from the shaft but is tapped to receive the wiper carriage fixing screw.*

When assembling the selector, the shaft is pushed upwards into the conical seating so that there is no side play, and then locked by the tightening of the clamp-securing screw (Fig. 113). The wiper carriage assembly should be free on the shaft when it is raised or lowered in the 12th rotary position, but the side play, if any, should be only just perceptible. The carriage restoring spring is tensioned by rotating the main shaft before it is finally clamped. When the carriage is in the normal rotary position, two to three complete turns should be given for 2-bank selectors, but this may have to be increased to four or five turns on larger selectors with up to, say, 4 banks. The tension is applied by lifting the carriage assembly to the 9th vertical position and then, after loosening the clamp-fixing screw, rotating the shaft in an anticlockwise direction (when viewed from above). The clamp-fixing screw is now retightened, care being taken to push the shaft firmly upwards before the final tightening. There is a drilling mark at the upper end of the shaft which can be seen immediately in front of the mechanism when there is no tension in the restoring spring. This is a useful index mark when adjustments are made.

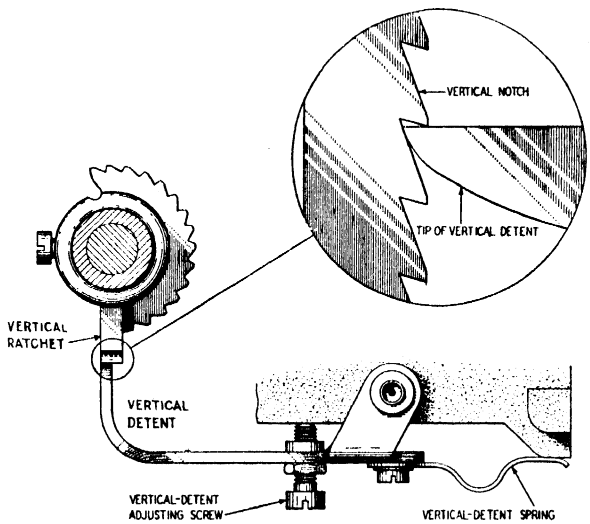


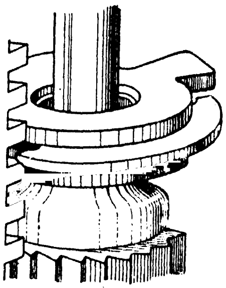
FIG. 114. ADJUSTMENT OF VERTICAL DETENT

The normal position of the selector carriage can be regulated by an adjusting screw located on the under side of the shaft securing clamp (see Fig. 113). When the selector is in correct adjustment, the rotary disc at the head of the wiper carriage should just clear (by 5–10 mils) the extended lug of the

comb plate. The provision of this gap ensures that the weight of the carriage, when normal, is taken by the clamp and not by the extended lug of the comb plate.

On the more recent deliveries, an "antibounce" plate of a heavy zinc-base alloy is fixed to the bridge plate of the selector. It has been found that this device materially reduces wiper carriage bounce on release.

Detent Adjustments. The vertical and rotary detents operate on a common bearing pin which passes through the selector frame. Vertical play in these bearings can be taken up by loosening a bracket clamping screw, pushing the bearing pin downwards, and then retightening the screw. Fig. 114 shows the vertical detent and its position in relation to the vertical ratchet. This detent carries the weight of the carriage during vertical stepping, but when the carriage is rotated into the bank the rotary disc at the head of the carriage hub enters a slot in the fixed comb. At the same time the vertical ratchet moves out of engagement with the detent. The weight of the carriage is then transferred from the detent to the comb plate at the first rotary step. It is important that the detent should be adjusted so that the rotary disc enters smoothly into the slot of the comb. If this is not correct, the detent should be set by bending the tip up or down so that, when the carriage assembly is rotated, the disc enters the comb slot without rise or fall (Fig. 115). The detent should also be level with the left-hand side of the vertical ratchet, and if this is incorrect lateral adjustment should be made by bending the detent. Finally, the adjusting screw should be set so that (with the carriage assembly raised to the 5th level) the tip of the detent just touches the bottom of the vertical tooth (Fig. 114). The detent spring bears against a projection of the selector frame and should be tensioned to exert a pressure of 110 ± 30 g when measured at the tip of the detent.



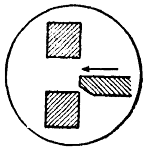


Fig. 115. Showing Entry of Rotary Disc into Slot of Comb Plate

Fig. 116 shows the rotary detent, its adjusting screw and restoring spring. When the wiper carriage is stepped vertically, a small clearance is necessary between the tip of the rotary detent and the short face of the first rotary tooth. This clearance should be as small as possible provided that the detent does not rub against the face of the tooth when the wiper carriage is stepped vertically.

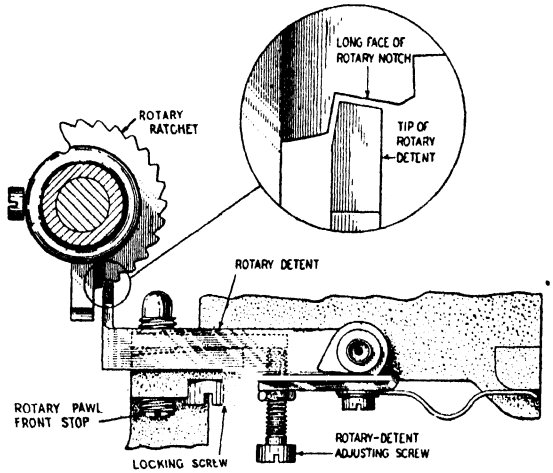


Fig. 116. Adjustment of Rotary Detent

Adjustment, if required, can be made by bending the tip of the rotary detent. An adjusting screw is provided for regulating the depth of engagement with the ratchet tooth. This screw should be set so that the tip of the rotary detent is just clear of the long face of the tooth (see Fig. 116). The rotary detent spring is tensioned so that the detent exerts

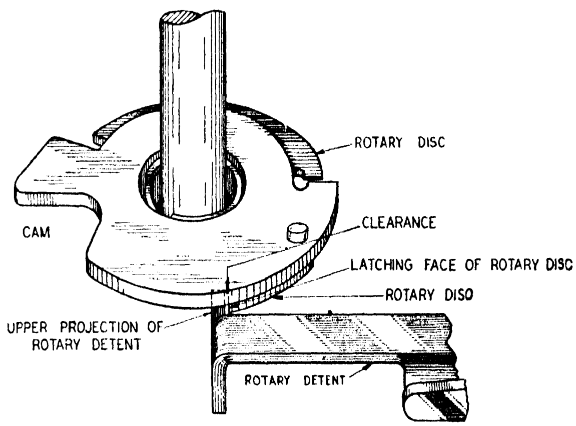


Fig. 117. Latching of Rotary Detent with Disc

a pressure of 130 ± 30 g when measured at the tip of the detent.

The rotary detent has a projection on its upper surface which latches with the rotary disc to prevent rotary movement when the wiper carriage is on the normal level (Fig. 117). If necessary the detent

should be adjusted (by bending it up or down) so that the upper portion is just clear of the under side of the cam when the carriage is returning on the normal level. At this point the lower portion of the detent just clears the top face of the rotary hub.

Vertical Magnet Assembly. The vertical magnet is of the single coil type with a cast-iron core of very large cross-section. During the development of the selector, various built-up and laminated cores of several materials were tried, but a one-piece construction of cast iron proved to be the most satisfactory arrangement. A simple one-piece casting, which includes the coil cheeks, is easy to manufacture and facilitates the dissipation of heat. Cast iron has a reasonable magnetic permeability and a high electrical resistance which minimizes the eddy currents and thereby permits high speeds of operation. The coil is wound with enamelled wire to 50 Ω resistance and is substantially "self protecting" when connected to a 50 V supply (i.e. the coil will not burn out if the current is allowed to persist).

The magnet and its associated armature and pawl is assembled as a complete sub-unit (Fig. 118). The complete unit is located in the selector frame by an extension of the armature bearing pin which enters a positioning hole in the frame casting. The vertical armature is made up of a plate of Swedish iron riveted to a bracket of steel which provides the lugs for the armature and pawl bearings. The pawl bearing is $\frac{1}{8}$ in. diameter stainless steel rod which is knurled and driven into the pawls and riveted over into serrated holes. This method of construction ensures that the bearing cannot come loose in service. The main armature bearing is of bronze, and is provided with a lubricating wick.

The procedure for adjusting the vertical magnet, the length of the armature stroke, and the position of the pawl back stop, etc., is briefly as follows:

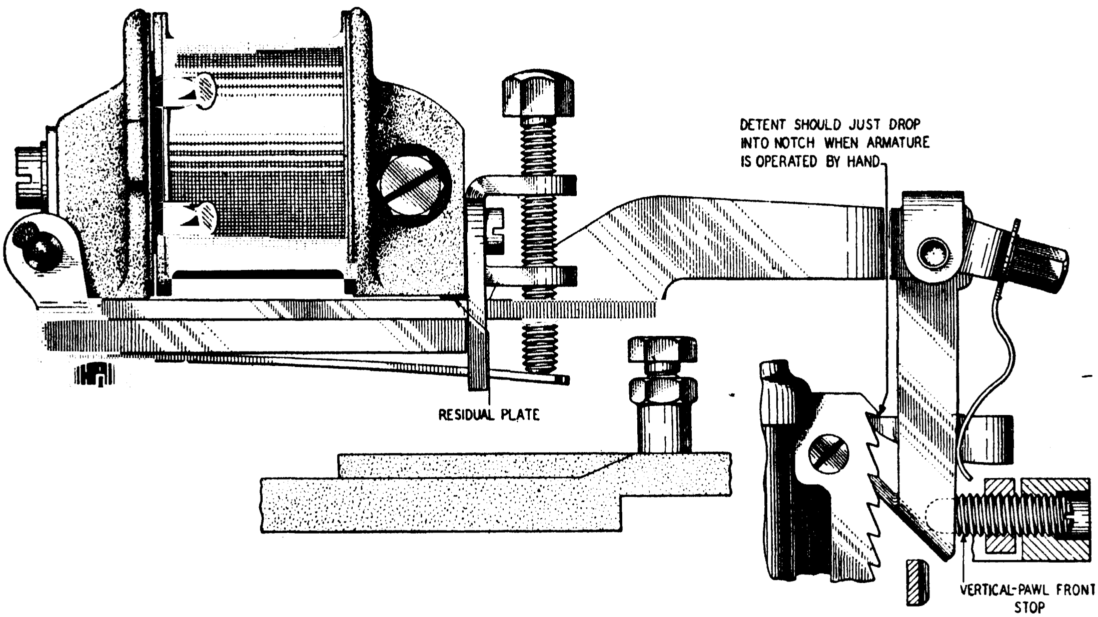


FIG. 118. VERTICAL MAGNET AND PAWL SYSTEM
(Magnet shown operated)

(*a*) The vertical magnet is first examined to ensure that both the armature and the pawl are free on their bearings with a minimum of side play.

(*b*) It is important that, when the magnet is energized, the armature strikes squarely on both faces of the magnet core. If this is not correct, the armature bearing pin clamping screws are loosened and the armature operated electrically before the clamping screws are retightened.

(*c*) The magnet assembly is located in the selector frame by pressing the extended armature bearing pin into the special hole provided in the casting. If the magnet fixing screw is loosened, the whole assembly is now free to rotate about this pin.

(*d*) With the magnet fixing screw loose, the whole assembly is pushed upwards, i.e. so that the armature travel is a maximum. The hexagonal-headed magnet fixing screw is now retightened.

(*e*) The vertical pawl front stop (Fig. 118) is

withdrawn clear of the pawl in its operated position.

(*f*) The vertical pawl is adjusted (by bending the armature lever) so that the left-hand edge of the pawl is flush with the left-hand side of the vertical ratchet. With this adjustment the vertical pawl should just clear the ratchet when the carriage assembly is rotated one step.

(*g*) The carriage assembly is now raised to the first level and the vertical pawl guide is adjusted (by bending with carriage in normal position) so that the tip of the pawl strikes into the root of the fourth vertical notch when the armature is operated by hand (Fig. 119). It is now possible to proceed with the adjustment of the armature stroke.

(*h*) The armature back stop is first unscrewed so that it lifts the vertical armature and the carriage assembly until the vertical detent drops over the first vertical tooth. The back stop is now unscrewed somewhat more, so that there is a slight clearance of some 5 to 10 mils between the short face of the vertical tooth and the detent.

(*i*) The magnet fixing screw is next loosened, and the magnet assembly is gently lowered until the pole face is just in contact with the armature.

(*j*) The magnet fixing screw is then retightened.

(*k*) The armature back stop is now screwed inwards so that the armature is lowered until the vertical pawl just moves over the tip of the vertical ratchet tooth. The back stop locking nut can now be tightened.

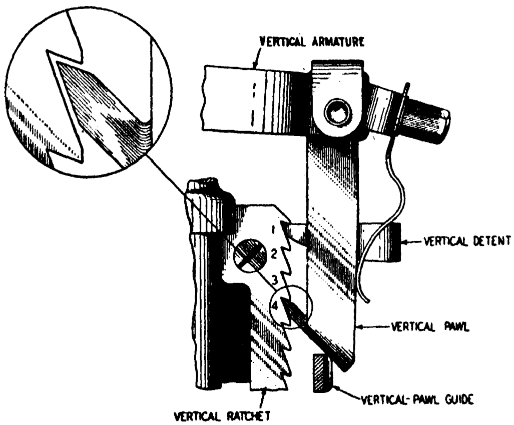


FIG. 119. ADJUSTMENT OF VERTICAL PAWL GUIDE

(*l*) The armature assembly is now in correct adjustment, and it remains only to position the vertical pawl front stop. This stop is screwed in until the vertical detent just drops into the root of the next tooth when the armature is operated by hand on any vertical step. This ensures that, when the vertical armature is operated electrically, the vertical pawl strikes its front stop slightly in advance of the vertical armature striking the magnet core. When the front stop is in correct adjustment, it is secured by the locking screw.

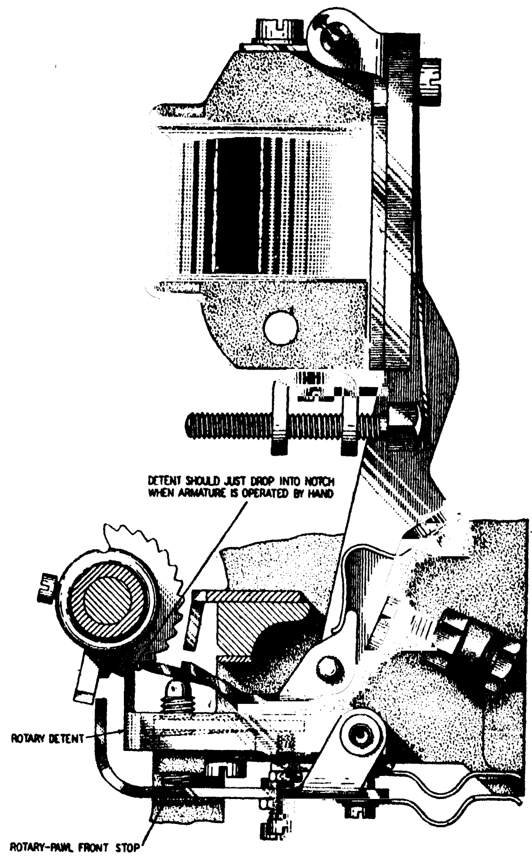


FIG. 120. ROTARY MAGNET AND PAWL SYSTEM
(Magnet shown operated)

(*m*) The vertical movement can now be checked by operating the armature electrically. Under these conditions there should be no vertical play in the carriage assembly and the carriage should not drop when the armature commences to restore.

(*n*) The pawl spring is tensioned to exert a pressure of 80 ± 30 g when measured at the tip of the spring with the vertical armature operated.

(*o*) Similarly, the vertical armature restoring spring is adjusted (by means of the screw) so that it exerts a pressure of 350 ± 50 g at the tip of the spring.

Rotary Magnet Assembly. The rotary magnet is of similar construction to the vertical magnet, and

utilizes the same type of cast-iron core. The magnet, its armature, and the rotary pawl are built up as a complete sub-unit which, like the

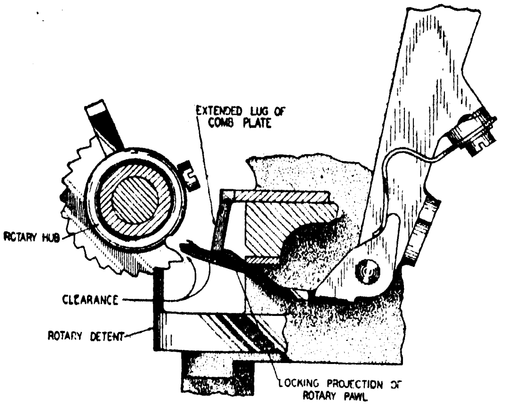


FIG. 121. LOCKING OF ROTARY PAWL ON 12TH STEP

vertical assembly, is located in the frame by the armature bearing pin (Fig. 120).

The adjustment procedure is briefly as follows:

(*a*) An examination is first made to check that the pawl and armature are both free on their bearings, and that the armature, when operated, strikes squarely against both faces of the magnet core.

(*b*) The magnet assembly fixing screw is first loosened, and the pawl front stop is withdrawn so that it is clear of the pawl in its operated position.

(*c*) The complete assembly is now swung to the left (i.e. so that the armature travel is a maximum).

(*d*) The magnet assembly fixing screw is now temporarily retightened.

(*e*) The assembly is inspected to ensure that the tip of the rotary pawl strikes squarely into the rotary teeth when the armature operates, and also that the pawl is clear of the rotary hub when the carriage is returning on the normal level.

(*f*) The pawl guide is set so that the pawl strikes into the fourth rotary tooth, and slides approximately one-third of the distance along the long face of the tooth.

(*g*) A check is now made to prove that, with the wiper carriage in the 12th rotary position, and with the armature operated, the locking projection of the rotary pawl locks securely behind the extended lug at the bottom of the comb plate (Fig. 121). The pawl locking projection should, however, clear the projection of the comb plate on all rotary steps except the 12th.

(*h*) The assembly is now in readiness for the adjustment of the rotary armature stroke.

(*i*) The armature back stop is withdrawn, and a special long screw is substituted and screwed in until the rotary pawl rotates the carriage up to the point where the rotary detent drops over the next rotary tooth and leaves a clearance of some 5 to 10 mils.

(*j*) The magnet fixing screw is now loosened, and the magnet assembly is rotated about the armature bearing until its pole face is just in contact with the armature. The magnet fixing screw is now retightened.

(*k*) The dummy back stop is also withdrawn and is replaced by the normal back stop. The latter is adjusted so that, when the rotary armature is normal, the tip of the pawl clears the long face of the third rotary tooth just sufficiently to allow the carriage to be raised from normal to the 1st level (Fig. 122).

(*l*) Finally, the rotary pawl front stop is screwed in until the rotary detent just drops into the rotary notch when the rotary armature is operated by hand (Fig. 120). This ensures that the rotary pawl strikes its front stop slightly in advance of the rotary armature striking the core face of the magnet.

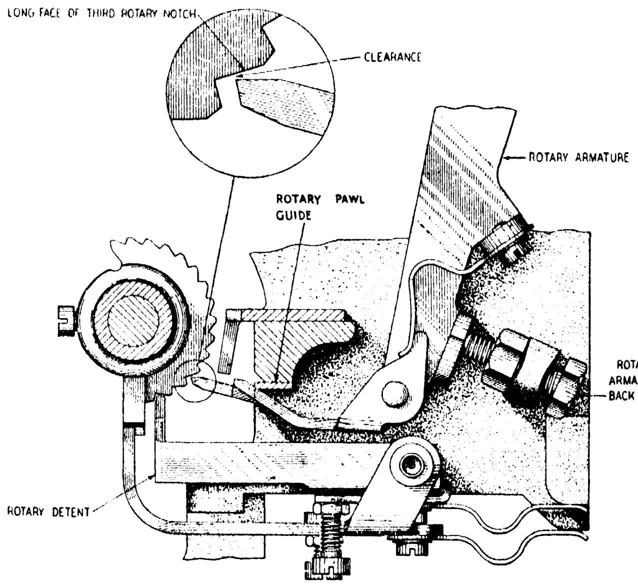


FIG. 122. NORMAL POSITION OF ROTARY PAWL

(*m*) The adjustments can now be checked by operating the armature electrically. Under these conditions there should be no rotary play in the carriage assembly, and there should be no backlash in the carriage when the armature commences to restore.

(n) The rotary pawl spring tension is 150 ± 30 g (as measured at the tip of the pawl with the armature normal).

(o) Similarly, the rotary armature restoring spring is adjusted so that it exerts a pressure of 350 ± 50 g (measured at the tip of the spring).

Mechanically Operated Contacts. Freedom from bounce and contact reliability are also required of the mechanically operated spring sets. All the spring sets of the 2000 type switch are of the same general design (Fig. 123), and are mounted together along the top of the selector frame. Twin contacts at the ends of flexible spring tips reduce the probability of contact failure, whilst moving and fixed springs of substantially different length very much reduce vibration. In the more recent productions the mechanically operated spring sets are of the "buffered" type to minimize contact bounce during operation.

All the mechanically operated springs (other than the interrupter contacts) are controlled from a fixed cam *A* (Fig. 124/1) and an auxiliary cam *B* attached to the head of the wiper carriage. Cam *A* is rigidly attached to the wiper carriage and consequently rotates with the wipers. Cam *B* is pivoted loosely and remains in the normal position shown until moved by a striking pin on cam *A* at the 12th rotary step. The off-normal, rotary off-normal and 11th step spring sets are operated by cam *A*, whilst cam *B* controls the operation of up to two sets of "level" (or N.P.) springs. The mechanical arrangements are as follows:

Off-normal Springs. These operate at the first vertical step and re-set at the end of the release movement. As the wiper carriage rises at the first vertical step the projection of cam *A* moves out of contact with the end of the off-normal lever (Fig. 124/2) and allows the latter to move inwards in the direction of arrow *C* under the pressure of the off-normal springs which is applied at *D*. Cam *A* traces out the path shown by the dotted line during the setting up and release of the selector. The off-normal contacts are thus restored by the final portion of the rotary return movement on the normal level.

Rotary Off-normal Springs. These springs operate at the first rotary step on all levels (except the normal) and release at the 12th rotary step. The wiper carriage must be moved vertically before the rotary off-normal springs can be operated. The first vertical step brings the periphery of the cam in line with the full diameter of the roller on the rotary off-normal lever *R* (Fig. 124/3). At the first rotary step the roller rides along the inclined face (*I*) of the cam and so moves the rotary off-normal springs in direction *B*. During the release of the selector, the roller drops into the recess (*D*) at the 12th rotary step thereby releasing the springs.

11th Step Springs. These operate at the 11th rotary step on all levels except the normal, and release at the 12th rotary step. At the 11th step, part *A* of the cam (Fig. 124/4) engages the roller (*R*) and moves it as indicated by arrow *B* to operate the springs. At the 12th rotary step, the roller falls into the cam recess (*C*) and the springs are released. As in the case of the rotary off-normal springs, the cam clears the roller during the reverse motion to the normal rotary position, due to the reduced diameter (*E*) at the bottom.

Level Springs. There are two independent assemblies of level or "normal post" springs. Each assembly can carry up to 3 springs, but if only one assembly is required the limit is extended to 6

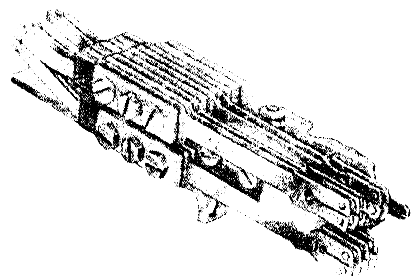


FIG. 123. TYPICAL MECHANICALLY OPERATED SPRING SET

springs. These springs operate on any chosen levels which are determined by fixing a small roller in any one of ten vertical positions. The springs remain operated whilst the selector is rotating to the 11th step but release on the 12th step. The two sets can operate on the same or adjacent levels and, by the substitution of cam plates for the rollers, can be held operated for a number of successive levels.

The auxiliary cam (*B*) (Fig. 124/5) rises and falls with the wiper carriage but it is only permitted to rotate through an angle of about 5° due to the presence of the comb in slot *E*. In the normal rotary position of the wiper carriage, the pin (*P*) holds the auxiliary cam so that the near side of the slot and the comb are almost in contact. As the wiper carriage rises, projections *C* and *D* of the auxiliary cam engage with the rollers and move the level spring levers in the directions shown by arrows *F* and *G* to operate the springs. Whilst the selector is rotating, the pressure of the level springs holds the rollers against the cam projections and prevents the auxiliary cam being rotated by the frictional drag of the fixed cam. At the

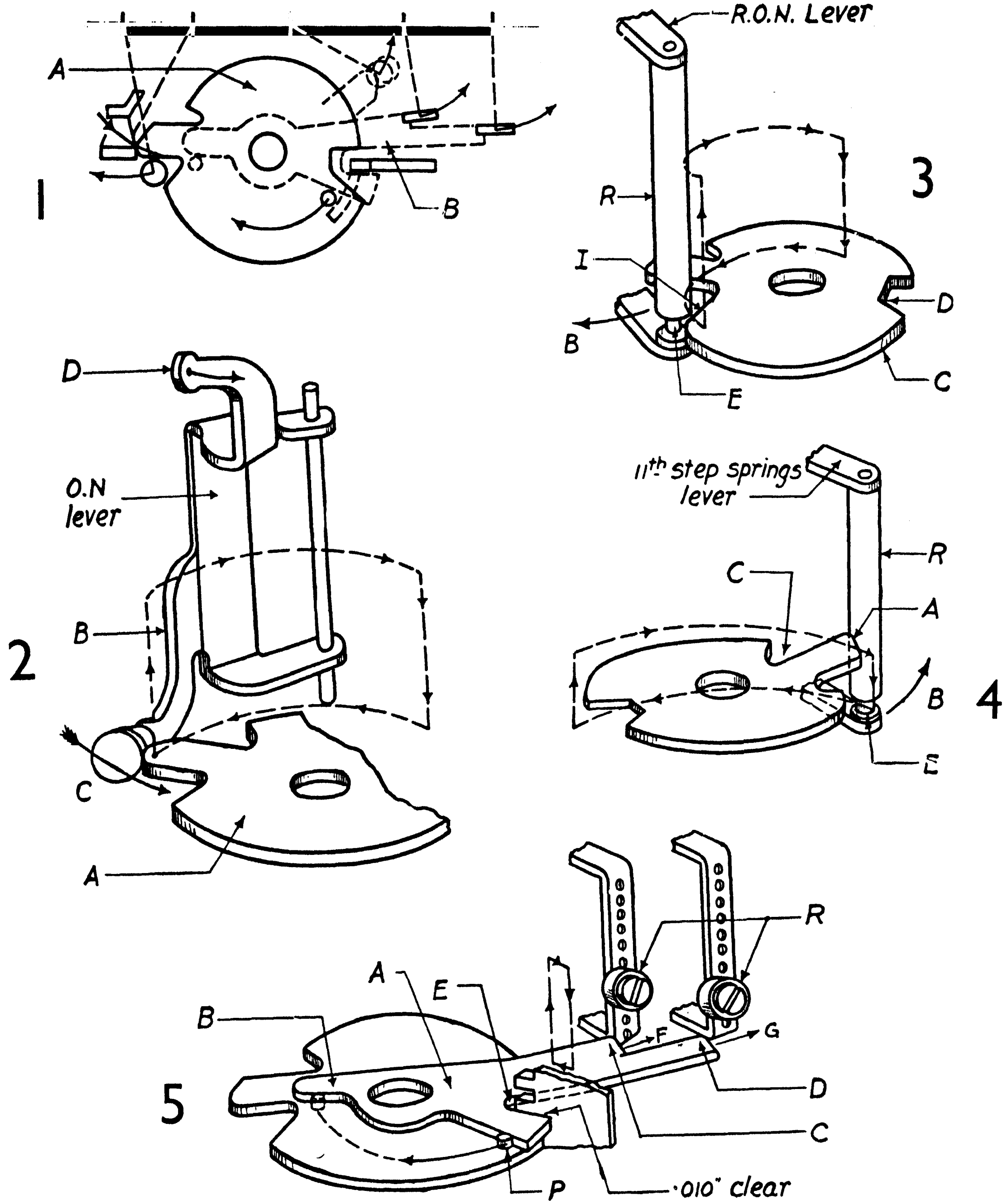


FIG. 124. CONTROL OF MECHANICALLY OPERATED CONTACTS

12th rotary step, however, the pin (P) engages with the tongue (B) and rotates the auxiliary cam until the projections (F) and (G) disengage from the rollers. The levers and springs then restore. The auxiliary cam extensions are held clear of the rollers during vertical release and the cam is finally restored to its normal position at the end of the reverse rotary action by pin P.

On later models of the 2000 type selector, the auxiliary cam is slightly different in shape and is fixed to the wiper carriage by a clamp extending to the under part of the main boss. The new part has been introduced to avoid vertical and side play which was found to develop in some cases.

The contact pressure of all make or break contacts should be 30 ± 10 g, the pressure being measured at the centre of the V between each pair of contacts (see Fig. 123). The contact units fitted to any particular selector vary with the circuit requirements. In most of the assemblies the intermediate make springs are buffered against the succeeding break or lever springs to minimize vibration during the operation of the mechanism.

Vertical and Rotary Interrupters. Whenever automatic drive is required, it is necessary to provide contacts which are operated by the vertical or rotary magnet. Until the advent of the 2000 type selector these contacts were of the simple make or break type, but in the 2000 type selector a new "toggle" interrupter (Fig. 125) has been

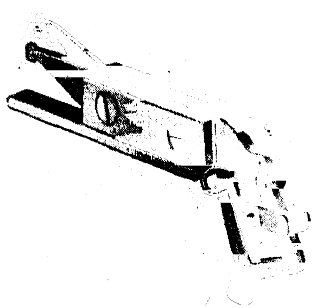


FIG. 125. TOGGLE TYPE ROTARY INTERRUPTERS

introduced. The need for, and the advantages of, this type of contact are fully described in Chapter VII, but it may be briefly stated here that the purpose of the toggle interrupter is to provide a late operation of the contacts on the forward stroke of the armature, with a corresponding late restoration of the contacts on the return stroke of the armature. These requirements are met by operating the contacts indirectly from an extension of the armature through a toggle mechanism. Movement of the toggle is controlled by a small loop spring so placed that, when the toggle is operated during the forward movement of the armature, it remains in its operated position until it is restored by a second

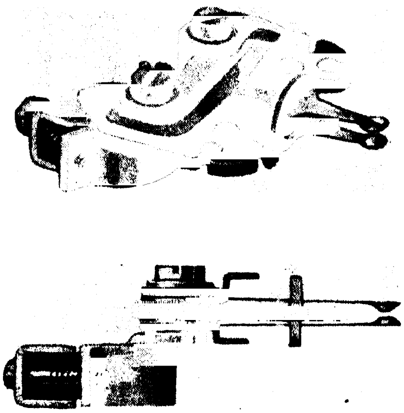


FIG. 126. WIPER ASSEMBLY

striker during the armature return stroke. The loop spring must have sufficient tension to carry the toggle over to its back stop against the tension of the interrupter springs, and to hold it in this position. The operating and restoring details are in the form of a U-shaped extension of the armature. The two arms of the U serve as operating and restoring strikers, and are so spaced that the correct timing of the contacts is obtained. It is important that there should be a clearance between the buffer of the toggle lever and the U-shaped striker both when the armature is normal and when it is operated; otherwise the interrupter spring assembly would interfere with the full restoration or operation of the associated pawl system.

Wipers. Selector wipers are possibly the weakest link in any system of machine switching. Light wiper pressures result in microphonic noises and generally bad transmission whilst, on the other hand, pressures which are too heavy very considerably reduce the life of the wiper and tend to cause failures. Wiper bounce is also an extremely important problem. In the extreme case, wiper vibration may cause jamming of the wipers at the first rotary step and, during rotary stepping, wiper bounce may cause failure of the testing and switching circuits. Even much less pronounced bounce often produces arcing at the contacts which rapidly destroys the wipers and banks. It has been mentioned in earlier paragraphs that wiper bounce can

be eliminated by making a wiper of such construction that the force tending to prevent the wiper leaving the contact (i.e. the wiper tension) is

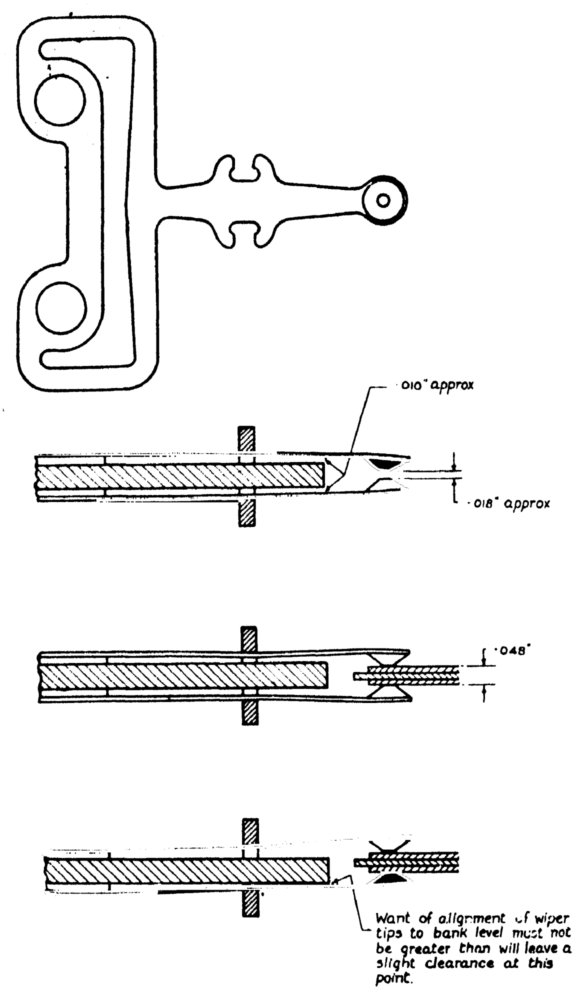


FIG. 127. DETAILS OF WIPERS SHOWING SELF-ALIGNING FEATURE

greater than the outward force due to the acceleration of its mass. Thus a short light wiper is more suitable than a longer one of greater mass.

The wiper of the 2000 type selector is illustrated in Figs. 126 and 127. The wiper springs are held together by a fibre collar located in notches a short distance back from the tips. During manufacture, the springs are bent outwards from the roots so that the tips are about $\frac{3}{8}$ in. apart before this collar is put on. It will be noted that the shape of the spring blank behind the collar is long and flexible. Between the wipers and extending through the collar to within a short distance of the tip, is a rigid plate of insulating material. The design is such that the only adjustments required on site are:

(1) With the wipers out of the bank, there shall be a clearance between the tips of 12 mils minimum and 20 mils maximum together with a perceptible clearance between the springs and the centre insulator.

(2) With the wipers on any bank contact, each spring shall be clear of the centre insulator.

The new wiper has the following advantages:

(*a*) The pressure exerted on the bank contacts is dependent upon the shape of the springs and on the amount of opening, so that accurate pressure is obtained by adjusting the tip gap only.

(*b*) The fibre collar anchors the two springs together so that they float up and down as a pair and equalize the pressure on the upper and lower bank contacts.

(*c*) The contact pressure is independent of slight variations of bank contact spacing.

(*d*) The clamping of the springs by the collar so near to the tip largely eliminates wiper bounce.

(*e*) The rigid central insulator limits the vibration of the wipers during vertical stepping and so minimizes "cut-in" difficulties.

(*f*) The tips are a truncated cone in shape and give a maximum life with freedom from "bridging"—even with the grossest maladjustment.

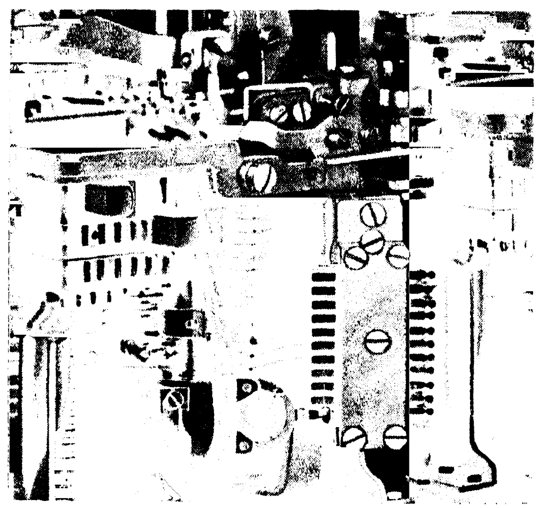


FIG. 128. VERTICAL MARKING BANK AND WIPER

(*g*) The wiper clamping arrangements (Fig. 126) enable any wiper to be removed or replaced without disturbing the remaining wipers or their cords.

The wiper assembly is positioned by means of the clamping screw so that the tip of the wiper is approximately one-third on the bank contact.

Vertical Marking Bank and Wiper. The vertical marking bank is mounted in front of the R.H. frame member on a bracket which is hinged on a vertical pin (Fig. 128). The bank can be swung forward and to the right (Fig. 129) to disengage the vertical wiper which is necessary before the selector can be removed from the shelf. The wipers are attached to a simple bracket which is free to rotate on the wiper carriage tube but moves vertically with it when the selector is stepped.

Selector Test Jack. The test jack of the 2000 type selector is of moulded bakelite and is designed on the unit principle to meet various circuit requirements. The top unit (Fig. 130) accommodates the selector lamp and the label, and provides a "parking place" for a U-link. The remainder of the test jack is built up of 6-spring units which are assembled to form a test jack of 6, 12, or 18 points. All test jacks are numbered in a standard way, i.e. from left to right and upwards. For ease of maintenance the test jack springs are, as far as possible, arranged in the circuit in a uniform way. The springs on a 12-point test jack (by far the most common) are, for example, usually allocated as follows:

1. Rotary magnet.
2. Private (or test and guard) wire.

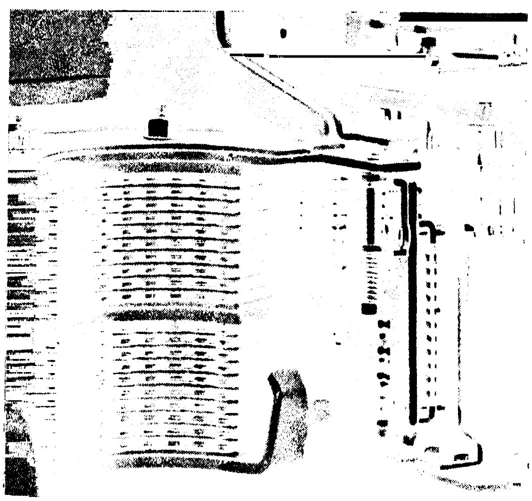


FIG. 129. MECHANISM REMOVED AND VERTICAL MARKING BANK SWUNG CLEAR

3, 4. First speaking pair.
5, 6. Second speaking pair.
7. Earth.
8. Private wire.
9, 10. Test bell circuit (on 200-outlet switches).
11, 12. Rotary release drive circuit.
13, 14. U-link parking place (on lamp and label strip).

A red capped U-link is normally kept in the parking place where it is not connected to the circuit. A

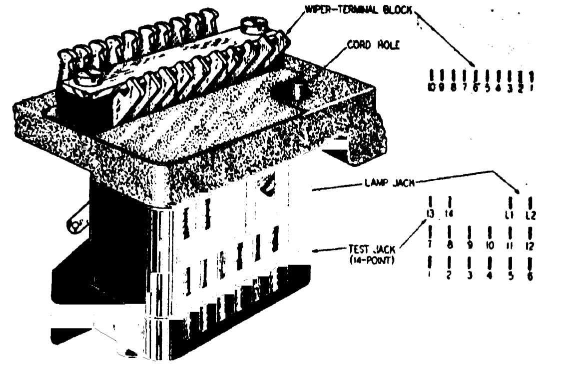


FIG. 130. SELECTOR TEST JACK

selector can be busied by removing this link to jack springs 7–8 and so connecting earth to the test (P) wire.

This link may also be momentarily inserted in springs 9 and 10 of 200-point selectors to determine whether an odd or even outlet has been seized (see Chapter VII).

A green headed link is permanently held in springs 11 and 12 where it completes the drive circuit for the rotary magnet on release. If, for test purposes, it is desired to prevent the release of a switch, this link is temporarily withdrawn.

Selector Plugs and Shelf Jacks. Each 2-motion selector is fitted with a plug which engages with the shelf jack. There are two standard sizes of plug providing 16 and 32 connexion points. The plug and jack terminals are commonly known as "U points" and are indicated on the relevant schematic diagrams by a small V together with the jack point number placed on the lead concerned, e.g. jack point No. 9 is represented by V9. For simplicity, the U points have been omitted from all the selector diagrams in this volume.

In order to maintain uniformity and facilitate maintenance, the U points are, as far as possible, allocated in a standard manner. The points are so designated that the odd-numbered U points start from the centre of the shelf jack (as seen from the rear) and count outwards towards the right. The even-numbered U points similarly start from the centre, and count outwards towards the left. The following allocations are adopted wherever possible:

1. — ve (in).
2. + ve (in).

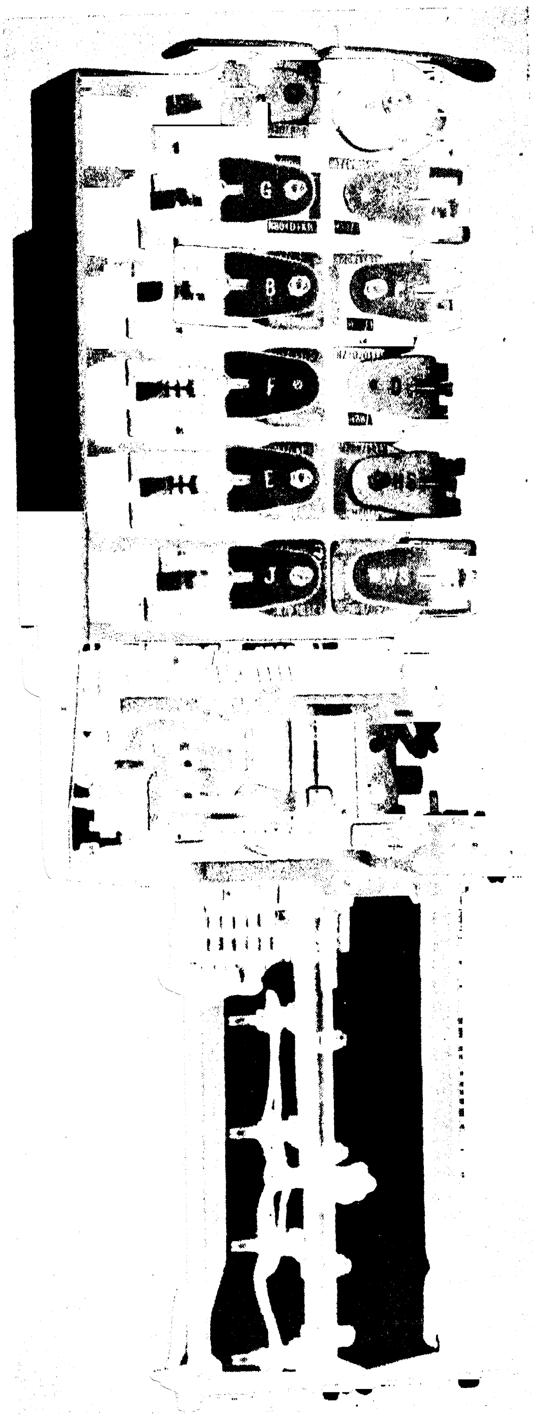


FIG. 131. TYPICAL 2000 TYPE SELECTOR
(200-outlet P.B.X. type final selector)

3. Ringing return earth.
4. + ve battery.
5. — ve (out).
6. + ve (out).
7. Private (out).
8. Dial tone.
9. *P*-wire.
10. C.S.H. or P.G. alarm.
11. Earth.
12. Battery.
13. Test trunk bell or interrupted earth.
14. Interrupted earth.
15. Release alarm earth.
16. Busy tone earth.
17. Flicker earth.
18. N.U. tone earth.
19. Ringing return battery.
20. As required.
21. As required.
22. As required.
23. Sleeve.
24. As required.
25. As required.
26. As required.
27. *S* pulse.
28. Interrupted battery and earth.
29. As required.
30. Ringing tone earth.
31. *Z* pulse.
32. Interrupted ringing.

Mounting of Relays and Other Apparatus. The relays associated with a 2-motion selector are invariably mounted on a pressed steel plate which is permanently fixed to the selector frame and which "jacks-in" with the selector. Fig. 131 shows a general front view of a typical selector with 11 relays and a number of resistors mounted on the front of the plate. The protecting cover guard will be noted at the top of the relay group. Fig. 132 gives a rear view.

There is space for one or two capacitors immediately behind the selector frame, but most of the miscellaneous apparatus is enclosed in a "capacitor box" which is immediately behind the relay mounting plate and is hinged to allow access to the wiring. Fig. 132 shows the capacitor box in its normal position, whilst in Fig. 133 the box is swung away to reveal the wiring. Braided cotopa covered wire is used throughout—red for earth, white for battery, and green for all other wires. The wiring is not laced but is tied together at intervals. The 32-point connecting plug which engages a similar jack on the apparatus rack appears below the wiring. Fig. 134 shows the interior of a typical capacitor box which houses two capacitors, a metal

rectifier, a resistor and a ballast resistor lamp. The arrangement of the wiring to provide the necessary flexibility should be noted.

Adjusting Tools. A complete set of tools is supplied for the adjustment of each type of selector. The tools naturally vary with the design of the switch, and there is insufficient space in this volume to give a detailed description of the methods of adjustment. Very briefly, the tool kit consists of:

(*a*) A series of bending tools or "adjusters," by means of which it is possible to regulate the position of the various levers, cams, detents, etc., of the switch mechanism.

(*b*) A series of tools for positioning and tensioning the mechanically operated contact springs and the wipers.

(*c*) A series of feeler gauges for checking contact

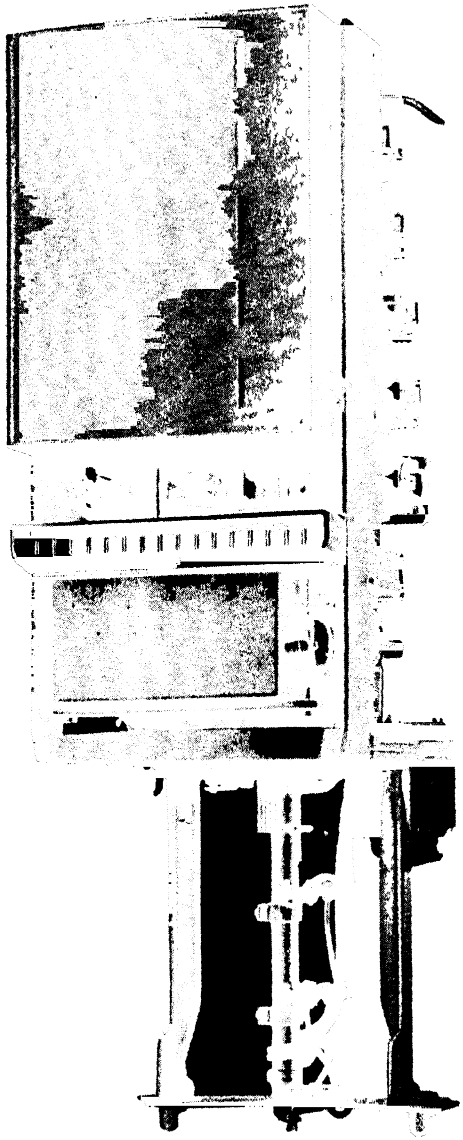


FIG. 132. REAR VIEW OF SELECTOR SHOWING CAPACITOR BOX

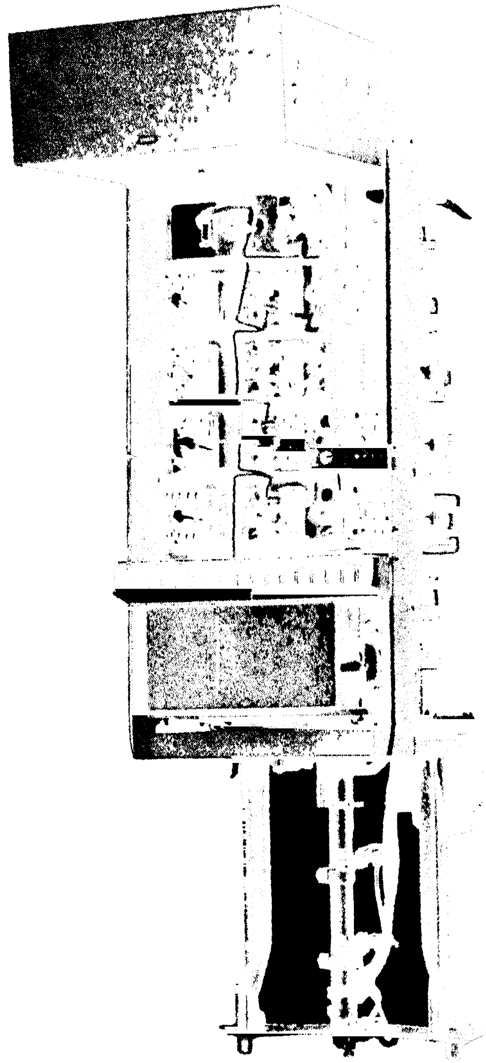


FIG. 133. CAPACITOR BOX SWUNG CLEAR TO EXPOSE WIRING

openings of mechanically operated springs and the adjustment of the pawls, detents, etc. There are several different forms of feeler gauges, some of which are made up of flat sheet steel, whilst others are round steel wire gauges of the required thickness.

(d) Tension gauges for measuring the pressures of mechanically operated springs, armature restoring springs, wipers, and many other parts of the selector.

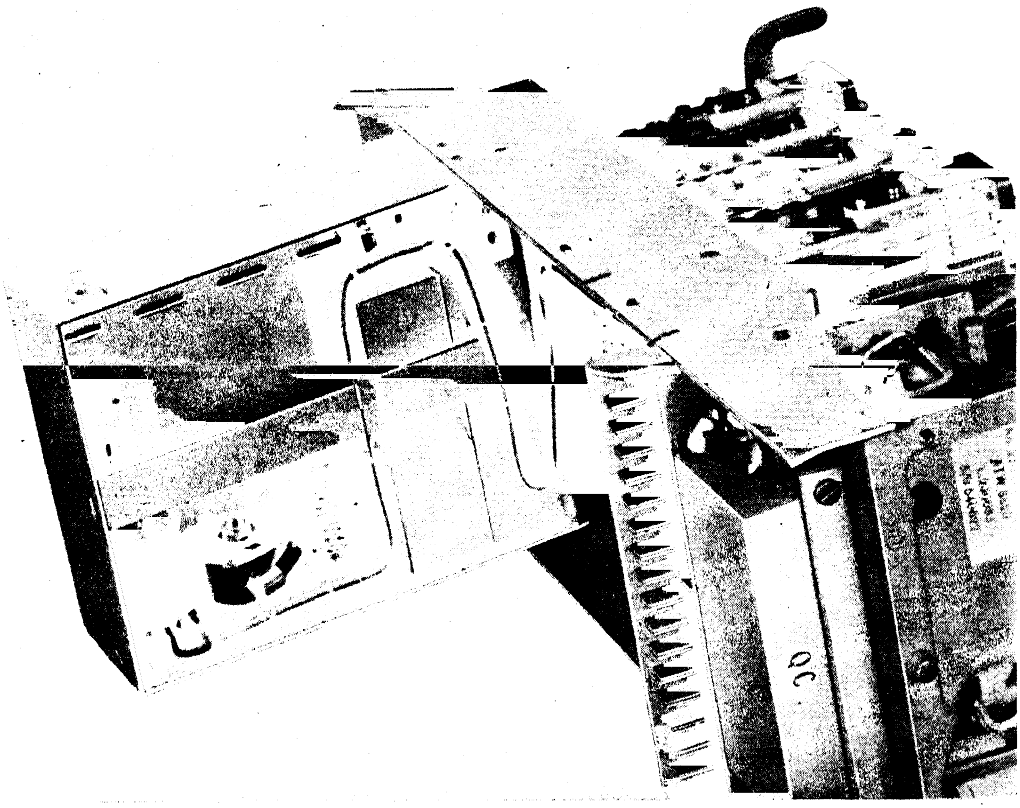


FIG. 134. SHOWING BALLAST RESISTOR AND OTHER APPARATUS MOUNTED IN CAPACITOR BOX

Fig. 135 shows a diagrammatic cross-section of a typical "tension gauge" used for checking contact pressures, etc., on telephone relays and automatic selectors. Detail C is designed to accommodate a removable probe D which can be applied to the portion of the selector or relay under test. When the probe D is inserted into the gauge, the spring-loaded swivel E locks it in the correct position until released by finger pressure on the extended portion of E. The triangular shaped detail C is riveted to a U-shaped bridge A, and the knife-edge extremities ride in V-shaped slots in the main body of the gauge B. A screw F passes through the centre of the U-piece, and provides a knife-edge bearing for the light plate G, the other end of which is attached to the main spring H of the gauge.

Tension on the main spring can be adjusted by means of the milled nut J, which rides on the threaded screw K, a pointer L being provided to indicate the tension in grammes. The arrangements are such that, when the gauge is adjusted to, say, 12 g on the scale, it requires a force of 12 g at the extremity of the probe D to lift the U-shaped bridge piece from one or other of its knife-edge seatings. The lever system is such that the deflection of D causes only a very slight build-up of pressure. This is an important feature of the gauge and materially facilitates the measurement of contact pressures, etc. The screw F can be adjusted to give equal deflecting forces when D is moved in either direction or, if desired, the gauge can be so adjusted as to provide a predetermined difference in deflecting force in the two directions. (This is

sometimes useful for checking that pressures are within certain close limits.) The gauge includes a counterbalance weight (not shown in Fig. 135) so that the reading obtained is independent of the position in which the gauge is held. When the gauge is not in use the probe D is removed and stowed in special clips fitted to the side of the gauge. It is usual to provide two probes to facilitate the use of the gauge under different conditions.

Lubrication of Switch Mechanisms. In order to ensure a high standard of service efficiency and to prevent undue wear, it is important to pay careful attention to the lubrication of automatic switch mechanisms. In the first place, the lubricant itself must have the correct characteristics. In choosing a lubricant for a particular purpose, the following factors should be considered:

(*a*) The lubricant should remain on the parts which require lubrication. In general, spreading or creeping is very objectionable on automatic mechanisms due to the possible bad effects on the electrical circuits.

(*b*) The lubricant should have a high degree of stability, i.e. it must not oxidize even when the mechanism is only used intermittently.

(*c*) The lubricant must not adversely affect insulating materials with which it may come into contact.

(*d*) If a lubricant is used on surfaces which require to be in electrical contact, the lubricant should prevent the formation of oxides or tarnish on the surfaces.

(*e*) The lubricant should have a high viscosity index and a low pour point when it is used on equipment in exposed situations or at unattended exchanges.

(*f*) It is desirable that the lubricant should form a visible film so that the maintenance staff can readily detect the presence or absence of lubricant. This question of visibility is of some importance where over-lubrication would be dangerous.

In the British Post Office a light bearing oil is used for the lubrication of the various spindles and bearings, whilst a heavily graphited oil (Oildag) is applied to the ratchets, pawls and similar parts of the mechanisms. In all cases the lubricant is applied by means of a small brush, which is slightly moistened with the appropriate lubricant. Apart from the more obvious points of lubrication, e.g. armature bearings, shaft bearings, ratchets, pawls and pawl bearings, it is usual to apply a small quantity of lubricant to the wiper tips of uniselector mechanisms.

For many years there has been some doubt as to whether or not lubricant should be applied to the bank contacts of 2-motion selectors. The presence of a small quantity of a suitable lubricant tends to reduce frictional resistance to the wipers and also to reduce the amount of wear. In addition, the presence of a thin film of lubricant tends to prevent the formation of oxides or tarnish on the contacts. On the other hand, experience has shown that the presence of oil on the bank contacts may, in certain circumstances, favour the accumulation of dust and introduce microphonic noise. In some cases the lubricant has had adverse effects on the bank insulation (particularly where varnished fibre is used). Whilst lubrication of the bank contacts of certain types of pre-2000 type selectors is permitted, the present practice prohibits the lubrication of the bank contacts on 2000 type selector mechanisms and on all selector mechanisms which are in frequent use, e.g. the selectors associated with the Director (q.v.). It is also forbidden to lubricate the P banks of all types of selector.

Where the bank contacts are not lubricated, they are burnished by means of velvet cloth or chamois leather, special tools being provided for the purpose. In the small number of cases where lubrication is permitted, the same procedure is followed, but the velvet cloth is saturated with oil before it is applied to the bank.

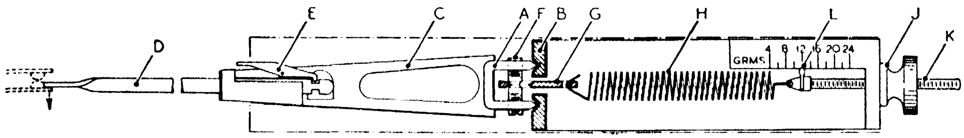


FIG. 135. DIAGRAMMATIC CROSS-SECTION OF TENSION GAUGE

EXERCISES III

1. What do you understand by the terms "forward-acting" and "reverse-acting" when applied to automatic selectors of the step-by-step type? Illustrate your answer with simple sketches.

2. Describe, with the aid of sketches, the more important features in the design of the ratchet and pawl system of a uniselector.

3. Explain how the impulsing performance of a selector is governed by:

(*a*) the resistance of the stepping magnet winding;

(*b*) the maximum load on the magnet armature;

(*c*) the need for adequate protection against the risk of fire.

4. Draw a graph to show how, in a 2-motion selector, the tractive force and the load vary when the switch makes one vertical step. At what point is the factor of safety a minimum?

5. Explain the action of the capacitor and resistor commonly used to quench excessive sparking from voltages induced in automatic switching circuits, and draw a diagram of the vertical magnet circuit of a group selector to show how such a device is connected. What values of spark-quench capacitance and resistance would be suitable for platinum impulsing contacts in such a circuit, and what would be the effect of short-circuiting the resistor? (*C. & G. Telephony, Grade III*, 1945.)

6. Sketch and describe the pawl and ratchet drive mechanisms of a 2-motion selector. Mention the points at which the adjustment of the mechanism must be particularly accurate, giving reasons. (*C. & G. Telephone Exchange Systems I*, 1948.)

7. Explain the essential differences in construction and operation between a uniselector and a 2-motion selector in respect of the following:

(*a*) Devices for conducting current continuously to the wipers.

(*b*) Armature action to move the ratchet one rotary step at a time.

(*c*) Shape of wiper tip for use in speaking circuits.

Give simplified sketches to illustrate the principles of operation described in cases (*b*) and (*c*). (*C. & G. Telephony, Grade I*, 1946.)

8. Describe the mechanical conditions under which each of the following contact assemblies on a 2-motion automatic selector is operated and released, giving in general terms the function of each in a typical circuit application. (Circuit diagrams are not required.):

(*a*) Vertical off-normal springs.

(*b*) Cam springs.

(*c*) Normal-post springs.

(*C. & G. Telephony, Grade II*, 1945.)

9. Describe the more important features of the high-speed motor uniselector. How is the wiper movement arrested when the required bank contact has been reached?

10. When a helical spring of n convolutions is subjected to a pull of P pounds, it changes in length by $\frac{64PR^3n}{Cd^4}$ in.

where,

R is the mean radius of the helix in inches,
d is the diameter in inches of the wire of which the spring is made,
C is the modulus of rigidity in pounds per sq. in.

A spring, of 1 in. effective length and 24 convolutions in the form of a helix with a mean radius of 100 mils, is made of wire 36 mils in diameter, the modulus of rigidity being 11×10^6 lb/sq in.

(*a*) Two such springs are used as armature restoring springs on a reverse-drive uniselector, and they are each extended to $1\frac{1}{4}$ in. when fitted on the uniselector. Determine the total pull exerted by the springs on the armature.

(*b*) If the springs are attached to the armature $\frac{1}{8}$ in. from the armature pivot, and the centre of the electromagnet coils act on the armature $\frac{3}{4}$ in. from the pivot, calculate the force required to be exerted by the electromagnet coils just to commence to operate the armature.

(*c*) To what values would the forces in (*a*) and (*b*) be changed, if the spring-retaining screws are adjusted to permit of 26 convolutions of the springs becoming effective? (*C. & G. Telephone Exchange Systems III*, 1948.)

CHAPTER IV

APPARATUS RACKS AND CABLING

We have so far examined the design of the standard automatic selector mechanisms used in the British Telephone System and the method of interconnecting these mechanisms to provide a suitable switching scheme. Before proceeding with the examination of the detailed circuit arrangements, it is desirable to show how the selectors are mounted on suitable apparatus racks and how these racks are cabled together to form a complete exchange unit.

Standard Racks. As far as possible all the equipment in an automatic exchange is mounted on racks of uniform and standard design. Fig. 136 (which is reproduced from Vol. I) shows the basic rack framework which has been standardized for 2000 type exchanges. There are two standard heights:

10 ft 6½ in. for installation in apparatus rooms which have a clear height of 12 ft below the beams.

8 ft 6½ in. for apparatus rooms where it is not possible to get sufficient clear height for the larger racks. These racks require a clear height of 10 ft.

Provision is made for four standard widths of rack:

Type A—4 ft 6 in. wide

Type B—3 ft 6 in. wide

Type C—2 ft 9 in. wide

Type D—1 ft 6 in. wide

Generally speaking, the 4 ft 6 in. racks are used for all selectors and relay sets, whilst the 3 ft 6 in. and 2 ft 9 in. racks are used for various types of strip mounted apparatus. The 1 ft 6 in. rack is used only for special equipment, such as routiners, traffic recorders, test racks, etc., where it would be uneconomical to use a larger rack and where the equipment cannot readily be mounted along with other apparatus.

The racks are constructed of mild steel angles (to British Standard Specification B.S.S. 4A). The main uprights are of 3 in. × 2 in. angle, whilst the top and bottom cross members are respectively of 2½ in. × 2 in. and 5 in. × 3½ in. angle. The vertical and cross members are rigidly fixed together either by welding, riveting, or by the use of countersunk bolts. The 3 in. flange of the right-hand upright member is provided with universal drillings at 4 in. centres to cater for miscellaneous common equipment mountings. The similar flange of the left-hand vertical is also provided with universal drillings for the standard power distribution scheme. Various other standard drillings are provided for the mounting of connexion strips, etc., on the top angle, for bolting the racks together, and for securing the racks to the floor. The 2 in. flanges of the main uprights are drilled as required to meet the requirements of individual racks.

In order to prevent accidental damage to the apparatus by ladders, etc., it is the standard practice to fit guard rails at the front and rear of all racks. The guard rails are of half round iron and run for the whole width of the rack at a standard height (6 in. clear) from the floor. The guard rails are fixed to the rack uprights by suitable angle brackets which are so dimensioned that the guard rails provide adequate protection to the apparatus and wiring.

Wherever possible the apparatus is arranged on the racks so that there is a clearance of 15 in. between the lowest portion of the apparatus and the floor. In exceptional cases this clearance can be reduced to 12 in. Similarly, in order to provide space for the mounting of terminal strips, etc., on the top angle iron, it is usual to restrict the height of the equipment so that there is a clearance of not less than 3 in. between the highest portion of the equipment and the top of the rack.

A designation plate, on which the code and number of the rack is engraved, is fixed to the front guard rail.

All rack frameworks are painted grey to B.S.S. 381 Colour No. 31.

Lay-out of Racks. The individual apparatus racks are erected side by side to form suites of racks. Each rack framework is rigidly fixed to its neighbours by bolts in the centre of the main angle uprights, and each rack is fixed to the floor by suitable coach screws.

All automatic apparatus racks are "single-sided," i.e. all the apparatus is mounted on one side of the rack, the reverse side being left free for the wiring between components and the cables to and from the rack. Most of the work on the apparatus racks is carried out from the front or apparatus side—except during installation the wiring behind the racks needs attention only at rare intervals. It is therefore usual to arrange the racks back-to-back in pairs with a narrow gangway in the wiring aisle, and a somewhat wider spacing

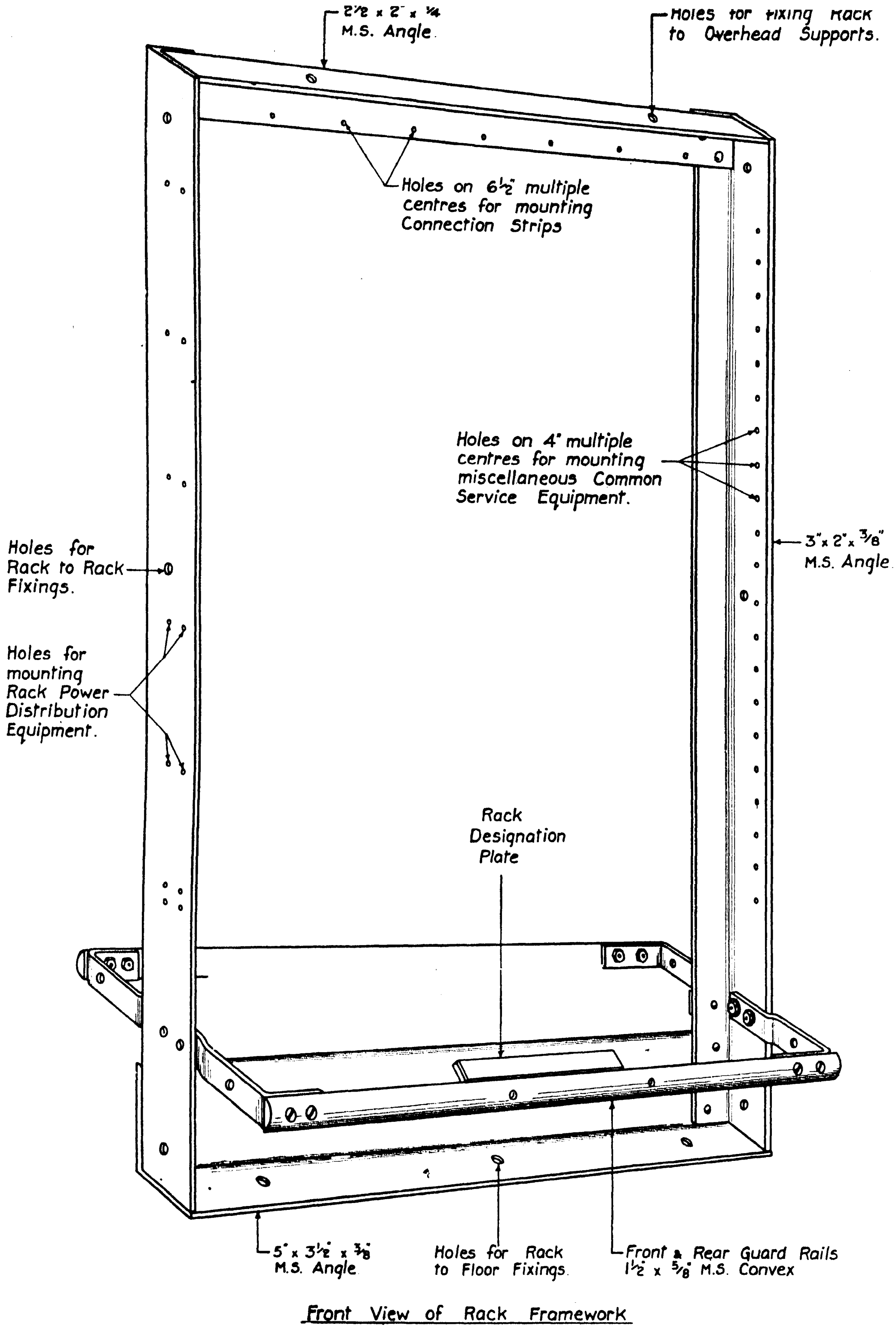


FIG. 136. FRAMEWORK OF STANDARD APPARATUS RACK

in the apparatus aisle. Figs. 137 and 138 show the standard spacing between suites of racks, the clearance dimensions of Fig. 138 indicating the distance between the outer edges of the rack guard rails. The suites of racks are connected together by inter-suite tie-bars which run at right angles to the face of the racks as shown by the broken lines in Fig. 138. Each tie-bar does in fact consist of two 1 in. × ¼ in. flat steel bars fixed close together with the longer side in a vertical plane. Apart from their primary function of holding the apparatus racks rigid, these tie-bars are also used to support ladder tracks, cable racks, lighting fittings, and so on.

Wherever possible the racks are arranged across, rather than along, the length of an apparatus room. Long suites of racks (say, more than five or six 4 ft 6 in. racks) are generally to be avoided on account of the difficulty of access and of obtaining natural lighting.

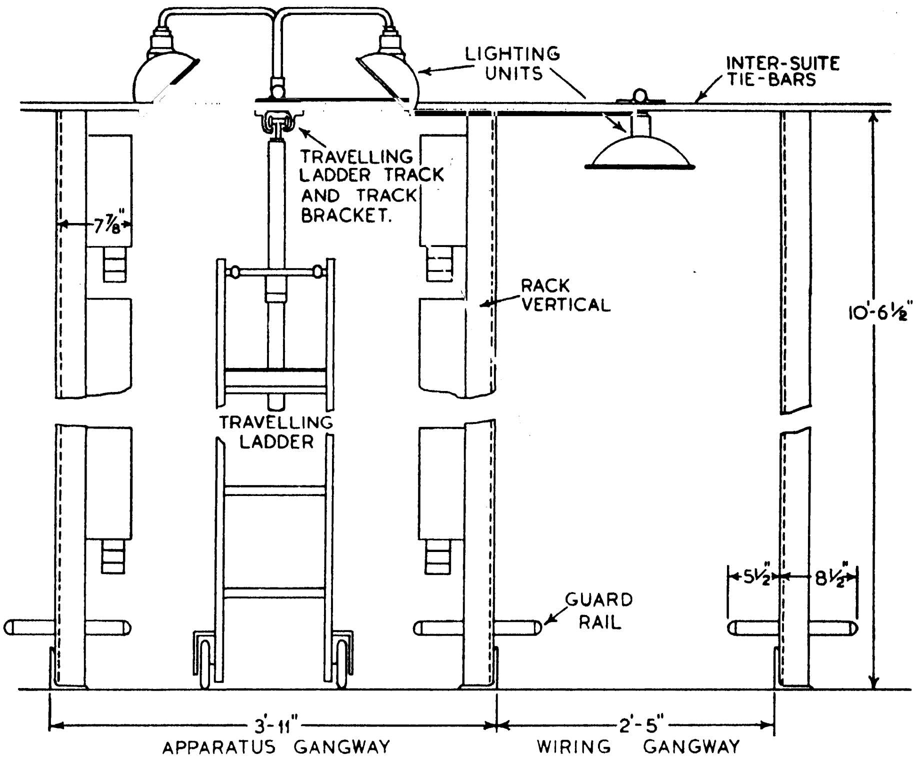


FIG. 137. LAY-OUT OF APPARATUS RACKS SHOWING STANDARD SPACING AND LIGHTING

Ladders and Lighting. In order to facilitate maintenance, it is the usual practice to provide travelling ladders in every apparatus gangway where the suite contains more than two standard racks. The standard ladder is of special design and is fitted with a brake to prevent mishaps which

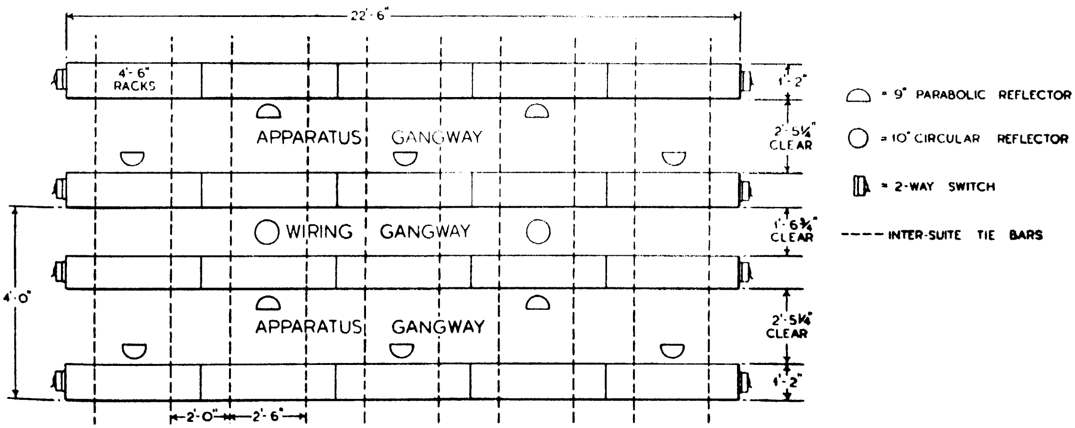


FIG. 138. FLOOR PLAN OF APPARATUS RACKS SHOWING POSITIONS OF INTER-SUITE TIE-BARS

might result from the accidental movement of a ladder whilst in use. Fig. 139 shows a portion of the ladder assembly. The ladder itself is of ash, and is equipped with a pair of rubber tyred wheels at the lower end. It is supported by a vertical mild steel tube which is suspended from a 4-wheel trolley. The trolley runs in a ∩-shaped track

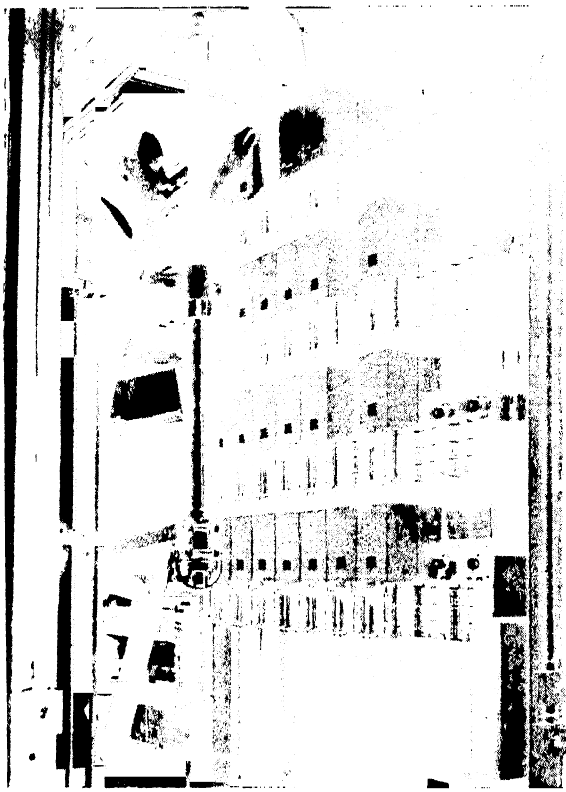


Fig. 139. Typical Automatic Apparatus Rack showing Travelling Ladder and Lighting Arrangements

which is rigidly bolted to the inter-rack tie-bars. Inside the main suspension tube there is a smaller tube which is spring loaded so that a brake shoe is normally pressed hard against the upper portion of the overhead track. To move the ladder, it is necessary to pull down the brake handle against the force of the brake spring. The ladder is so designed that it can be placed at any angle relative to the racks and, when it is not in use, it can be hooked on to the guard rail of any convenient rack.

Modern automatic exchanges are provided with a system of rack lighting. The apparatus gangways are illuminated by means of a number of lamps in parabolic reflectors, the lamps being so placed that substantially the whole face of one apparatus rack is illuminated from a lamp unit mounted immediately above a rack on the opposite side of the gangway (see Figs. 138 and 139). Simple pendant lights are provided in the wiring gangways. All the rack lighting is controlled from switches placed at the end of each suite of racks. Often 2-way switching is employed so that any desired gangway can be illuminated from either end of the suite. Further lighting facilities are available by the provision of sockets for hand lamps on the bottom cross members of some racks.

In the larger exchanges a travelling lighting unit is provided on the main and intermediate distribution frames. These lighting units are fitted with parabolic reflectors somewhat similar to the rack lighting points, but the whole unit is mounted on a trolley similar to that of the travelling ladder, and the lamp can be positioned to any desired point. In addition to the general "mains lighting" of an exchange, every apparatus rack is provided with battery jacks on the apparatus and wiring sides. Small inspection lamps are available for use in conjunction with these jacks for a more detailed examination of the apparatus.

Mounting of Selectors. On selectors of the pre-2000 type, the banks were attached to the selector frame direct by means of two bolts. It was necessary therefore to unbolt the banks before a selector could be removed from the rack and, once the selector was withdrawn, the banks were entirely unsupported. It is an important feature of the 2000 type switch that the selector can be "jacked-out" without disturbing the bank. This is achieved by the introduction of an accurately made pressed steel cradle (Fig. 140) to which the banks are bolted. The cradle is fitted with a number of rubber buffers to minimize vibration and microphonic noise, and is fixed by means of a single screw to a standard $2\frac{1}{2}$ in. × 1 in. channel iron girder mounted horizontally across the rack. The cradle also mounts the shelf jack which engages with the selector plug. The selector sits on the base of the cradle which determines the vertical location of the mechanism with relation to the banks. Bayonet type slots in the sides of the cradle and at the bottom of the selector frame, together with the spacing between the cradle sides, ensure the accurate positioning of the selector in the two horizontal directions. Jacking-in of the selector is extremely simple. The bottom of the side members is located first, with the selector inclined forward (Fig. 141) and the whole selector is then swung back and pushed down into the shelf jack.

Fig. 142 shows a complete shelf with accommodation for 10 selectors. The bank wiring is

multipled along the shelf and is formed out to a number of connexion strips fixed to the back of the shelf by means of suitable die-cast brackets (Fig. 143).

The arrangement of the cabling and wiring behind the selector shelf is shown more clearly in Fig. 144. The bank multiple cable form (which, incidentally, contains 600 wires for a 200-outlet selector) is tied to the under side of the brackets which support the terminal strips, and is laced out to the various tags along the length of the shelf. The outgoing cables to the next switching stage are formed out along the top side of the same brackets and immediately behind the terminal strips. The incoming wiring to the selectors and the local wiring between the selector jacks is formed out on top of the brackets behind the outgoing cables.

It is not always necessary to provide terminal strips for each shelf of 10 selectors. In a large number of cases, as many as 5 or more shelves of selectors may have a common multiple with only one set of connexion strips. In these circumstances the connexion strips are usually located on the highest shelf served by the multiple (in order to reduce the length of the outgoing cables). When a continuous multiple is provided over several shelves, the wiring arrangements behind the shelves which do not have terminal strips, are as shown in Fig. 145. A smaller and lighter bracket now suffices for holding the small incoming and local cables.

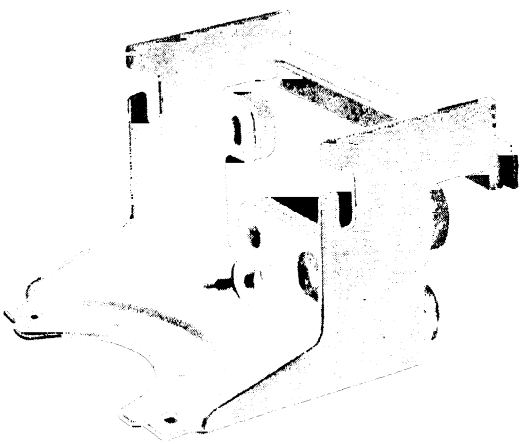


FIG. 140. SELECTOR CRADLE

In other circumstances there may be two or more separate multiples (each serving one or more shelves) which are to be commoned together and served by a single group of outgoing cables. This facility is provided by local shelf-to-shelf tie cables between the terminal strips of the several multiples. When such tie cables are provided, they are located as shown in Fig. 144.

FIG 141. PLACING SELECTOR IN CRADLE

A sheet metal dust cover is provided to enclose the bank terminal strips and the shelf cabling. This cover is attached by fixing screws to the bracket behind the shelf, and is readily removable for inspection purposes (see Figs. 144 and 145).

Mounting of Uniselectors. The standard uniselector is usually mounted on an angle iron frame (Fig. 146), which in turn is bolted to a single sided apparatus rack. It is the invariable practice to mount the uniselectors with the wipers in a vertical plane and with the mechanism driving magnet at the top. With this arrangement any dust, metal rubbings, etc., fall down to the lower portion of the bank, where they can be readily removed. Mechanisms of up to 5 levels are fixed at 2 in. centres so that a total of 20 uniselectors (together with 2 connexion strips for the termination of the incoming wiring and the outgoing multiple) can be

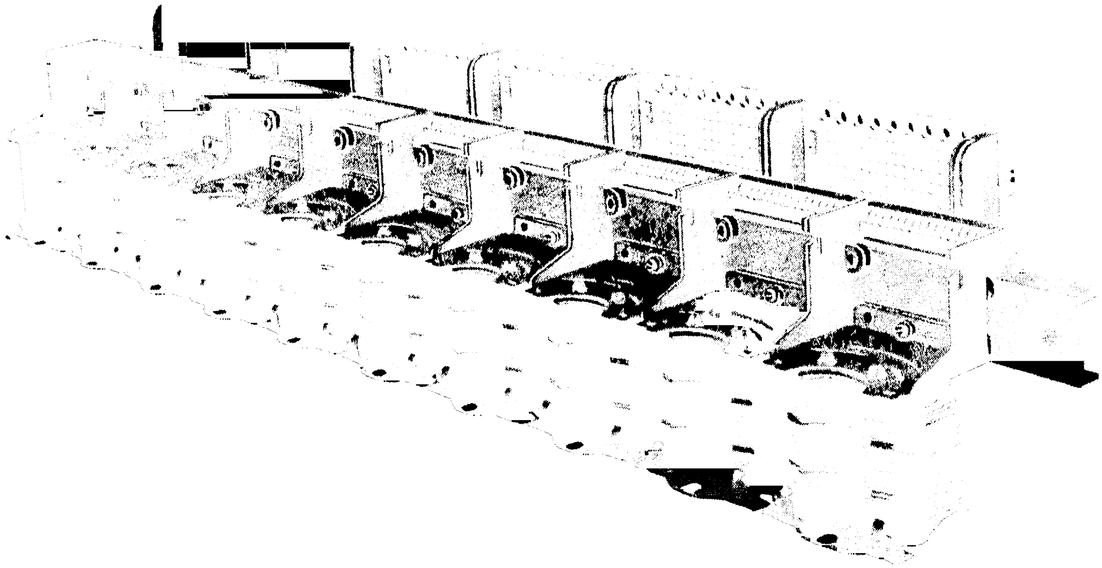


FIG. 142. SELECTOR SHELF COMPLETE WITH BANKS AND MULTIPLE TERMINAL STRIPS

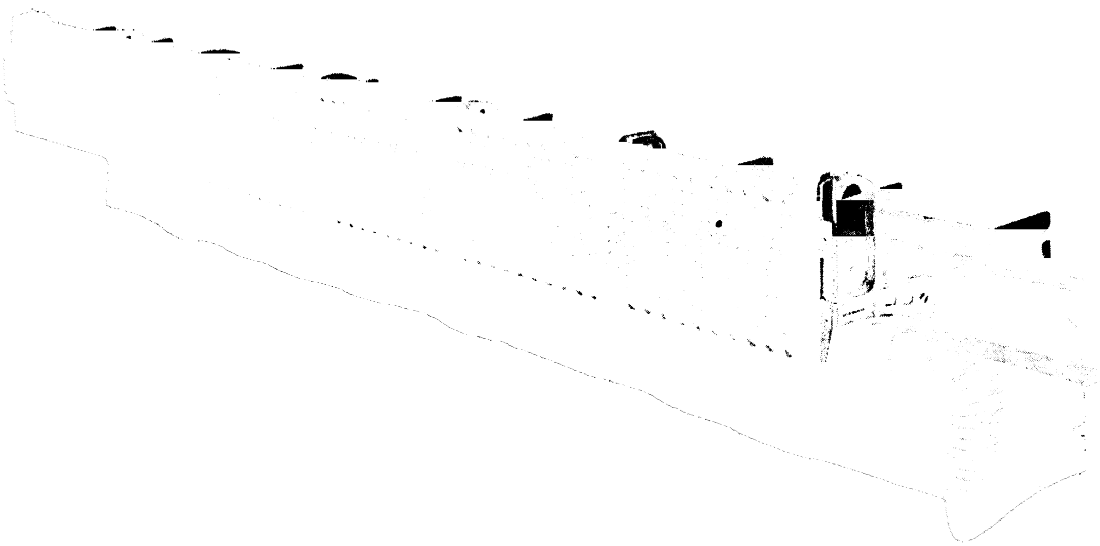


FIG. 143. REAR VIEW OF SELECTOR SHELF SHOWING BANK MULTIPLE TERMINATIONS

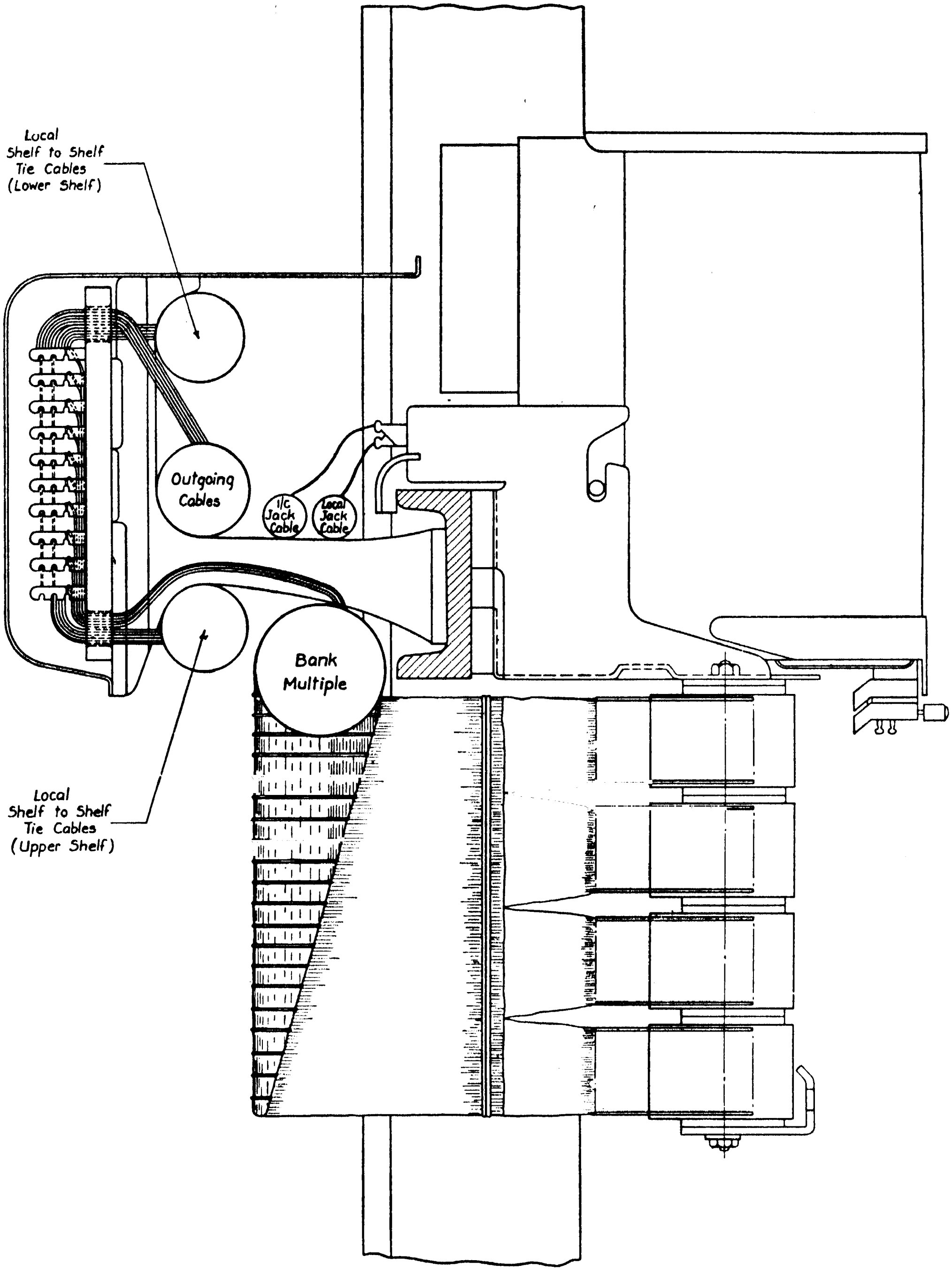


FIG. 144. END ELEVATION OF SELECTOR SHELF SHOWING RELATIVE POSITIONS OF CABLES, BANK MULTIPLE FORMS, ETC.

accommodated on one horizontal frame of a 4 ft 6 in. rack. The new No. 2 and No. 3 type uniselectors are somewhat smaller and 25 of these switches can be fitted on one shelf of a 4 ft 6 in. rack. Twelve such shelves and the associated controlling relays can be accommodated on a 10 ft 6 in. rack.

In order to prevent microphonic noise between adjacent switches, all uniselectors are mounted on spring clips as shown in Fig. 146. The mounting holes in the angle iron are fitted with ebonite bushes and these, together with paxolin washers, effectively insulate the uniselector frame from the rack.

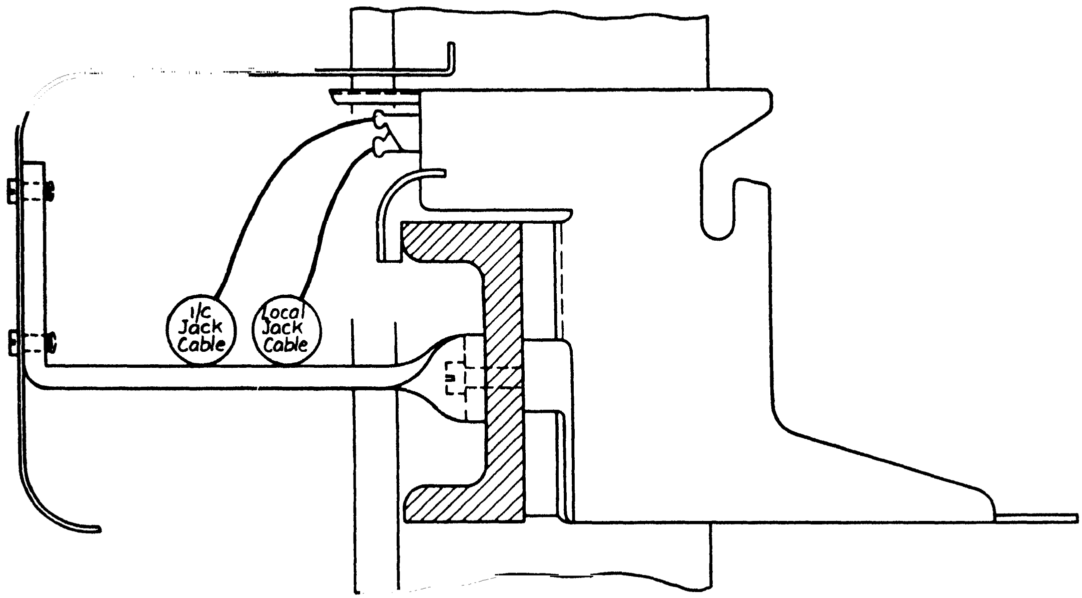


FIG. 145 END ELEVATION OF SELECTOR SHELF WITHOUT BANK MULTIPLE TERMINAL STRIPS

Mounting of Relay Sets. The relay sets in a 2000 type automatic exchange are designed for mounting on the same type of channel shelf as the selectors. Each 4 ft 6 in. wide shelf will accommodate 10 relay sets which are jacked into specially designed cradles screwed to the front of the shelf (Fig. 147). (These cradles are somewhat different from the selector cradles (Fig. 140) and do not incorporate the antivibration buffers of the latter.) The relay set jack is mounted immediately above the shelf and the cables are fed to this jack along simple brackets attached to the rear of the shelf. Removable dust covers protect the wiring. Two-channel type shelves, one above the other, are used when very large relay sets are to be accommodated.

The capacity of an apparatus rack depends, of course, upon the size of the relay sets to be accommodated. The capacity of a standard 10 ft 6½ in. high, 4 ft 6 in. wide, rack is as follows:

No. of Relays per Relay Set	No. of Relay Sets per Rack
8	120
10	120
12	100
14	100
16	90
18	80
20	70

The left-hand portion of Fig. 148 shows a miscellaneous collection of relay sets, selectors and uniselectors, mounted on the same rack. The relay sets on the lower shelves are of the 2000 type, whilst the top shelf accommodates 6 relay sets of the pre-2000 type which are mounted on a pressed steel channel type shelf. The different methods of mounting the two types of relay set are clearly indicated. This illustration also shows how a few miscellaneous selectors can be intermixed (exceptionally) with relay sets on the same shelf by the provision of the appropriate type of cradle.

The right-hand portion of Fig. 148 gives a rear view of a typical selector rack. The dust cover is removed from the third shelf to expose the bank terminal strips. This illustration also gives a clear impression of the inter-suite tie-bar system, of the rack lighting, and of the travelling ladder runway.

Mounting of Miscellaneous Apparatus on Relay Set and Selector Racks. Accommodation is required on most relay set and selector racks for various relays, keys, U-links, and so on, which are associated with the common services of the rack (i.e. tones, alarms, etc.). Most of this miscellaneous apparatus is located adjacent to the right-hand vertical member of the rack. There is a number of different types of mounting, but each mounting plate or panel is of a standard width. Each panel is provided with two or more fixings at 1 in. centres. The 3 in. flange of the right-hand rack upright is provided with universal drillings at 4 in. centres, and the mounting plates, etc., are screwed direct to this flange. This arrangement makes it possible to mount a varied assortment of miscellaneous apparatus whilst still retaining standardized apparatus panels.

The small panels required for keys, U-links, battery jacks, and so on, are fixed to small rectangular sheet iron boxes, which are screwed direct to the rack upright in any desired order. The front of the box is hinged to permit inspection of the wiring.

Fig. 149 shows a typical panel designed to accommodate 5 relays associated with the rack alarm

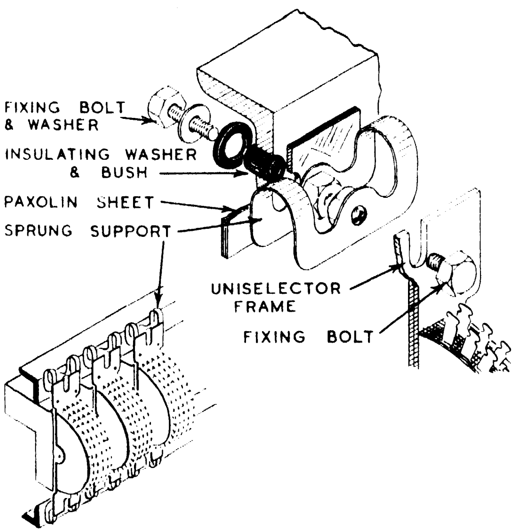


FIG. 146. SPRING CLIP MOUNTING FOR UNISELECTORS

circuits. This particular panel fits into a special cradle fixed to the rack upright.

The connexion strips required for the termination of the miscellaneous rack wiring (tone, alarm, ringing leads, and so on) are located at the back of, and fixed to, the top member of the rack. Standard drillings are provided in this member to meet the requirements of all racks.

The standard method of distributing power on the racks is described in Chapter XXVII.

Labelling and Marking of Racks and Equipment. A well-conceived system of rack labelling can do

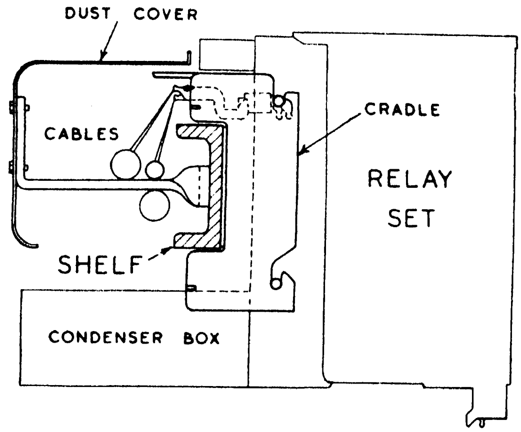


FIG. 147. END ELEVATION OF RELAY SET SHELF

much to assist the maintenance man in the location of apparatus. Every apparatus rack has a rack designation label fixed at an angle to the front guard rail. This designation plate displays the distinguishing code number of the rack. The following designations have been standardized:

Uniselector Racks. The racks are numbered US1, US2, etc., in sequence right throughout the exchange. If the rack serves coin-box lines only, it is usual to prefix the main rack designation with CCB (or BT).

1*st Selector Racks.* 1st selector racks are invariably designated by the rank of the switches, i.e. "1st" followed by the code letter of the rack. For example, 1st A, 1st B, 1st C, etc.

Intermediate Group Selector Racks. The designation commences with the level or levels of the previous switching ranks which have access to it, followed by the rack code letter, e.g. 3A, 3B, 3C indicates the first three racks of 2nd selectors which are accessible from level 3 of the 1st selectors. If a rack serves two levels it is given a combined code, e.g. 3D/4A.

Final Selector Racks. The racks are designated in numerical order, e.g. FS1, FS2, FS3, etc.—irrespective of the numbering of the multiple on the racks.

In director areas there are code selectors, tandem selectors and numerical selectors, and the simple code (e.g. 1st A) requires amplification. It is the usual practice, in these circumstances, to prefix the code with the letters C, T or N respectively.

In addition to the rack label, the designation letter of each shelf is indicated on a small label

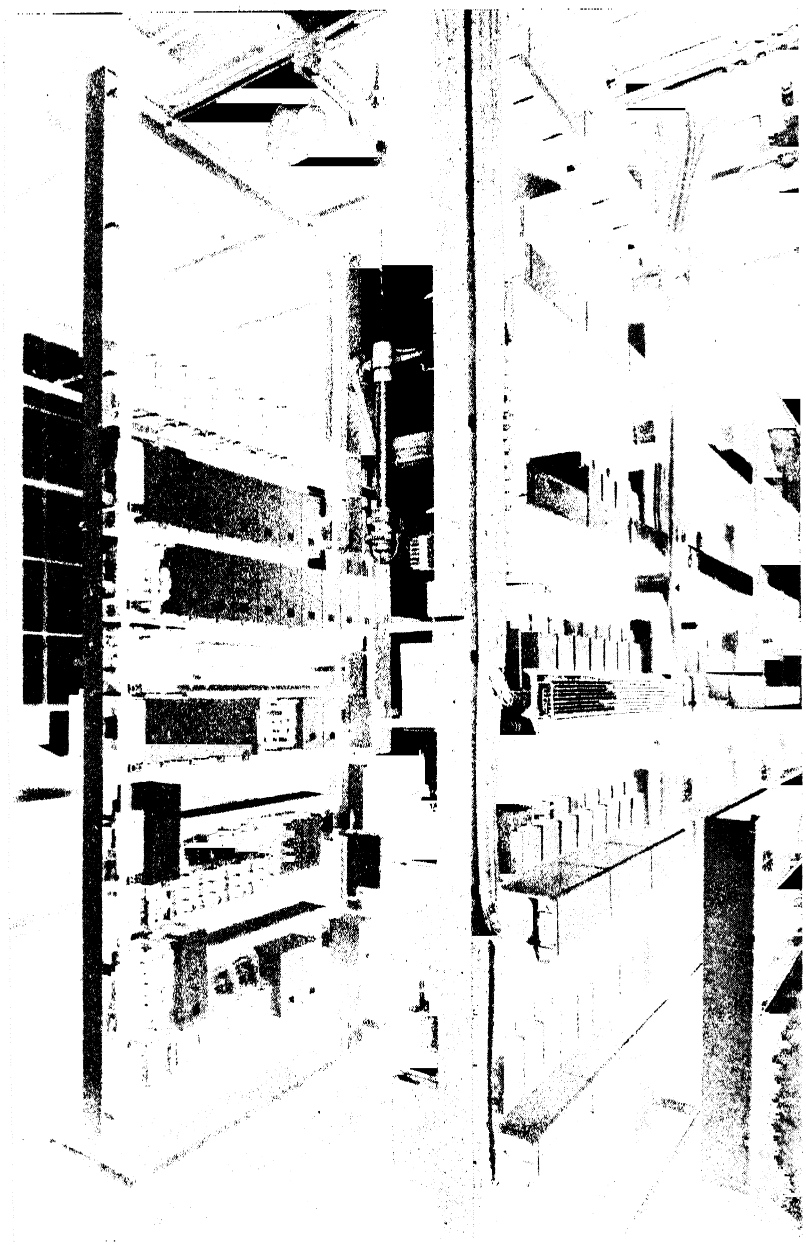


FIG. 148. RELAY SET RACK AND REAR OF TYPICAL SELECTOR RACK

at the left-hand end of the shelf. This label also includes subsidiary information, e.g. the hundreds groups of final selector multiple on the shelf.

It is also the standard practice to mark all connexion strips with the number of the circuit and the designation of the lead, e.g. $-$ ve, $+$ ve, P, etc. In the same way, all relays, resistors, etc., are sign-written with the circuit designation of the component.

Subscribers' Uniselector Rack. The subscribers' uniselectors are mounted on angle iron frames designed to fit across a standard 4 ft 6 in. rack (Fig. 150). Each shelf can accommodate 20 No. 1 type or 25 No. 3 type uniselectors. The bank multiple of the uniselectors is terminated on a connexion strip at the right-hand end of the self (as seen from the front). The associated line and cut-off relays (L and K relays) are equipped on suitable mounting plates immediately above the uniselectors. A standard 10 ft 6½ in. high rack accommodates 10 shelves of No. 1 type uniselectors, or 12 shelves of No. 3 type switches, i.e. it provides for a total of 200 or 300 subscribers respectively.

The incoming cables are tied to the rear of the left-hand upright, and are formed out as required to the incoming connexion strips of the various shelves. It is not necessary to cable out the bank multiple from each shelf separately. The exchange trunking scheme is, in fact, usually designed so that each group outgoing to the grading point consists of the traffic from a number of uniselector shelves. The various shelf multiples are in practice connected together by means of intershelf tie cables with a single cable leading from one shelf of the group to the grading point. There are some advantages in grading the outgoing trunks on the uniselector racks.

It is probable that, in the near future, a new design of uniselector rack will be produced to give grading facilities on the same principle as the new group selector racks (see p. 145).

Meter Rack. The subscribers' meters in a modern automatic exchange are of the No. 100 type already described in Vol. I. The meters are assembled in units of 40 (i.e. two rows each of 20) on special mounting plates designed to fit a 2 ft 9 in. apparatus rack. The right-hand portion of the mounting plate accommodates a jack panel which is required to obtain access to the meter connexions for routine test purposes. In exchanges of up to 2400 lines, it is usual to limit the number of meters to 600 per rack in order to facilitate meter reading. In the larger exchanges this is somewhat wasteful of rack space, and each 2 ft 9 in. rack is equipped for 1000 subscribers' meters, and a travelling platform is provided for meter reading.

Fig. 151 shows a typical meter rack. The routine test equipment is located under the cover near the bottom of the rack.

Linefinder and Associated Equipment Racks. If the exchange utilizes a linefinder scheme with partial secondary working (see Chapter II), the subscribers' line relays are concentrated on special "*L* and *K* relay" racks as shown on the left of Fig. 151. Each rack is 3 ft 6 in. wide, and is provided with a number of horizontal frames each of which accommodates 10 relay mounting plates. A 10 ft $6\frac{1}{2}$ in. rack has a capacity for 9 such panels, i.e. it will serve a total of 900 subscribers. The

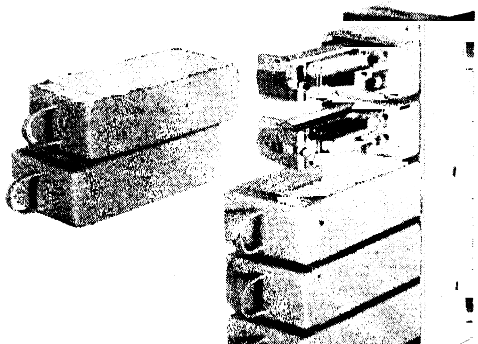


FIG. 149. ALARM CIRCUIT RELAY MOUNTING PLATE

relays are of the 600 type, and the external wiring is formed out direct to the relay tags.

Fig. 152 shows three racks of primary finders. These are 3-bank selectors but they are comparatively small due to the fact that there are only 2 relays in the finder circuit. A standard 10 ft $6\frac{1}{2}$ in. rack will accommodate up to a maximum of 7 shelves of primary finders together with the associated control equipment. The primary finders are arranged in "groups," each group serving a maximum of 200 subscribers. The number of primary

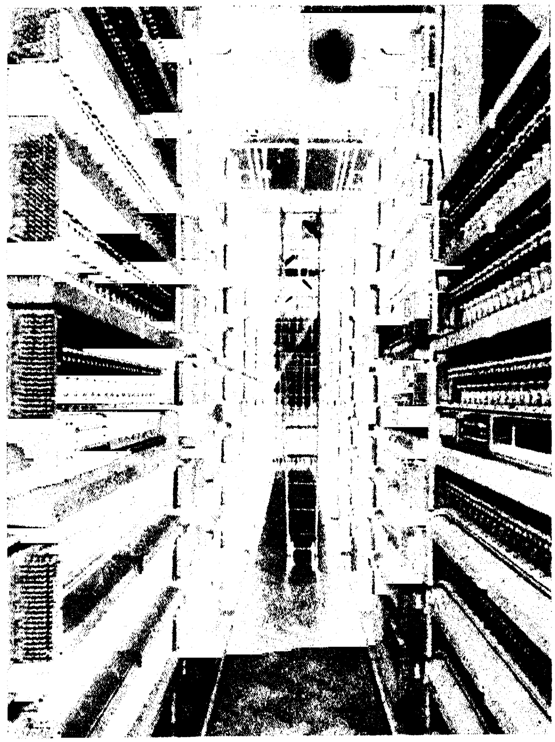


FIG. 150. SUBSCRIBERS' UNISELECTOR RACKS

finders required per group depends upon the subscribers' calling rate. In some exchanges 20 linefinders may be sufficient to serve a group of subscribers at the ultimate date, but in more busy exchanges there may be as many as 50 primary finders per group. The primary finder shelves are therefore multipled in accordance with the traffic requirements of each individual exchange, each multiple being connected to terminal strips behind a suitable shelf. One of the disadvantages of a linefinder scheme is the necessity for providing a linefinder multiple which will be sufficient to meet the ultimate calling rate. In some cases (especially where it is difficult to anticipate the development of an area), this may result in a somewhat wasteful provision of primary finder banks during the early life of the exchange.

The control and start relay sets are located on the bottom shelf of each rack, whilst the associated regular and auxiliary allotter uniselectors are fitted to a panel immediately above the control sets.

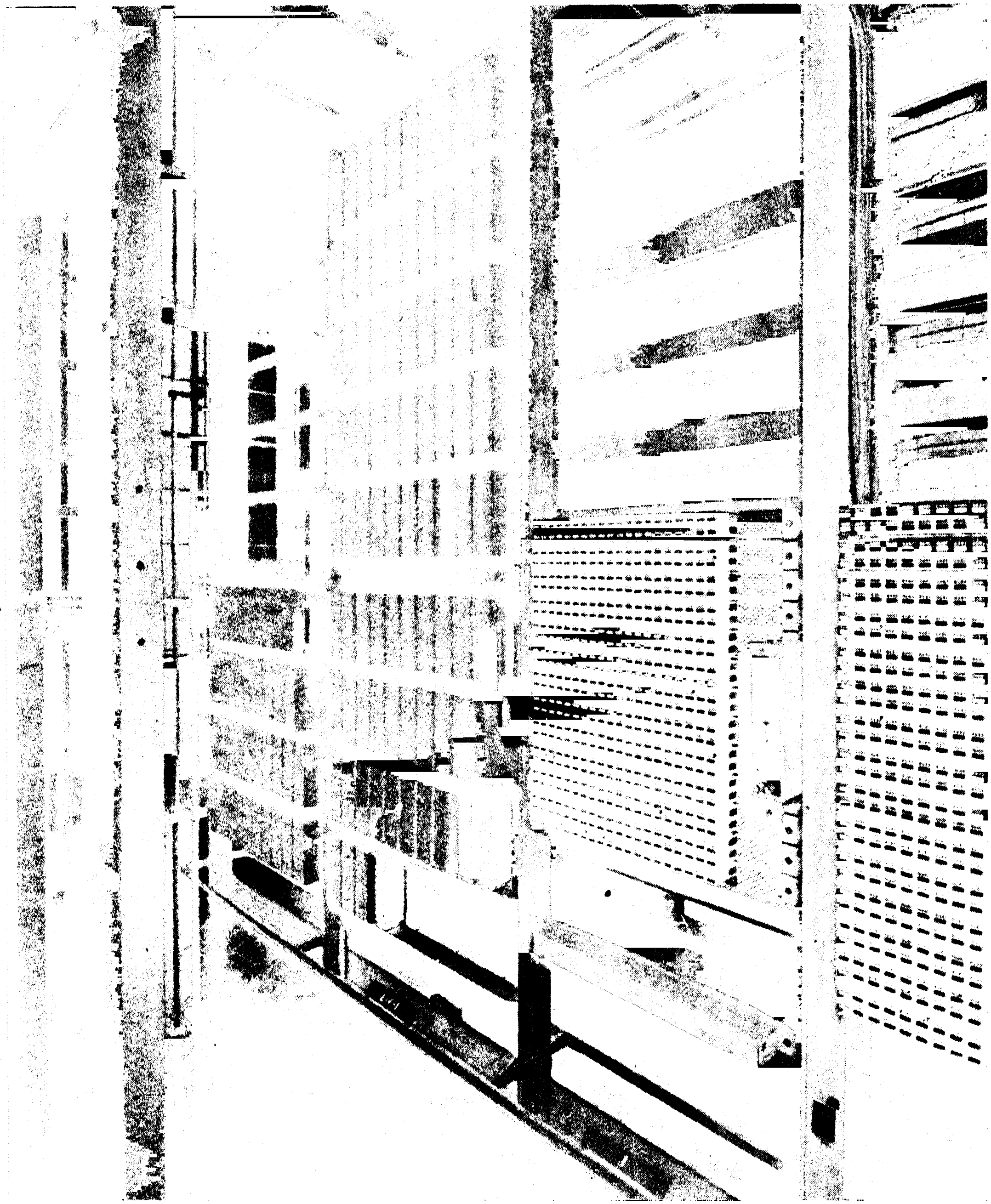


Fig. 151. Line Relay and Meter Racks

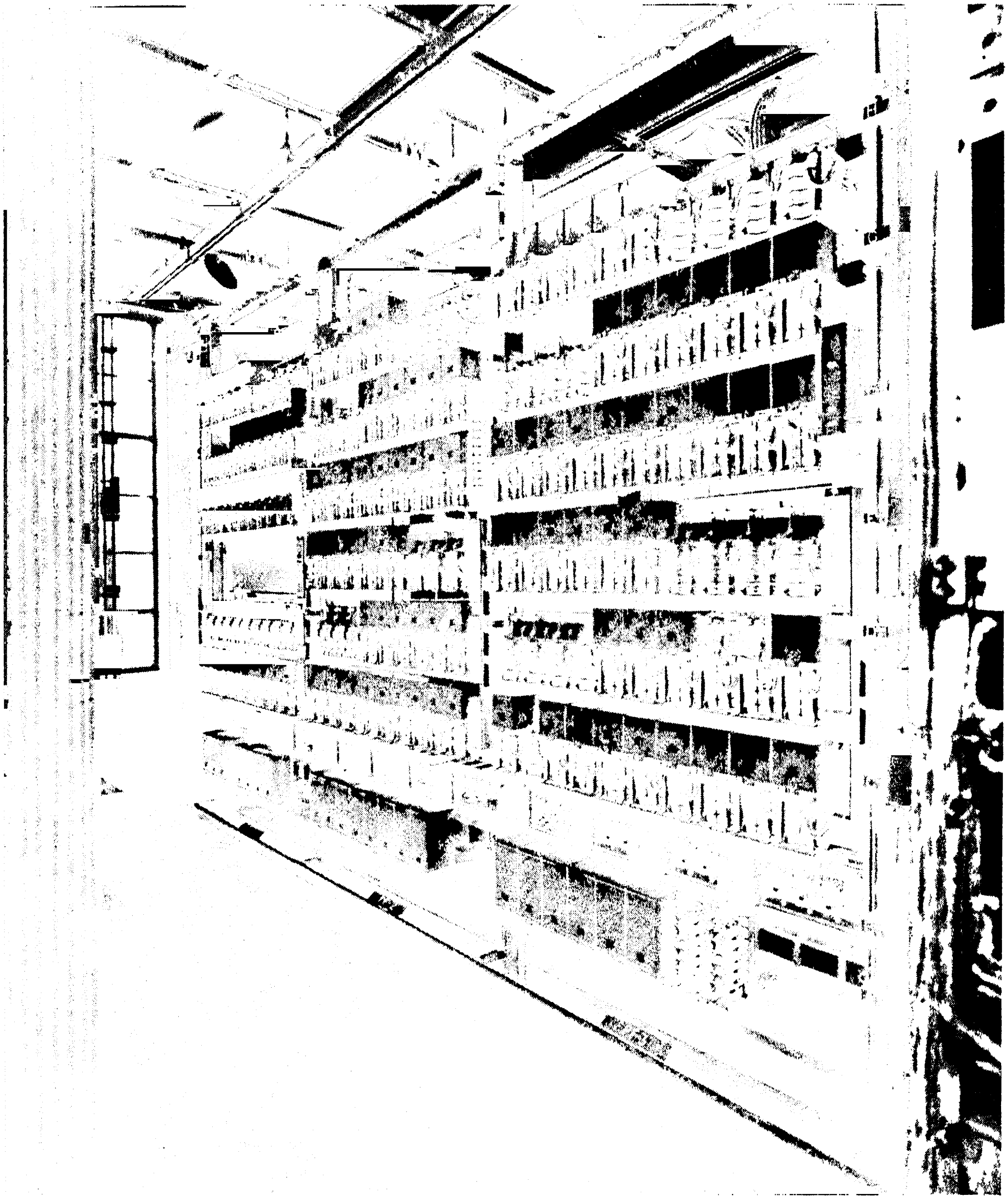


FIG. 152 PRIMARY FINDER RACKS

The various types of miscellaneous apparatus panel on the right-hand vertical will be noted.

The secondary finders are usually mounted on a separate 4 ft 6 in. rack and are arranged in groups which may vary in size depending upon the traffic density. Fig. 153 shows two groups each of 20 secondary finders with a multiple to provide up to 25 finders per group at the ultimate date.

Group Selector Racks. Fig. 154 shows the layout of apparatus on typical group selector racks. A standard 10 ft 6½ in. rack provides accommodation for 8 shelves of 200-outlet group selectors, i.e. the total capacity is 80 selectors. The smaller 8 ft 6½ in. rack will accommodate 60 selectors of the 200-outlet type. Group selectors of the 100-outlet type are not used to any extent in modern telephone exchanges, but, where such selectors are required, the standard rack (10 ft 6½ in.) will accommodate 90 selectors.

The arrangement of bank multiples depends upon the cabling and grading system employed. If grading is not done on the group selector rack, then the multiple is continuous over several shelves to provide the required grouping arrangements for the grading scheme. The current standard practice utilizes a system of grading on the shelf terminal strips, the exact arrangements being described in later paragraphs.

Final Selector Racks. Fig. 155 shows part of a suite of final selector racks. There are a number of different types of final selector to cater for ordinary lines and various sizes of P.B.X.s. The number of relays varies with each type of selector, and hence the rack capacity also varies. The main types of selector and the number of such selectors which can be accommodated on the standard rack are:

	10 ft 6½ in.	8 ft 6½ in.
100-line final selector (ordinary or 2/10 P.B.X.)	70	50
200-line final selector (ordinary or 2/10 P.B.X.)	60	40
200-line final selector (11 and over P.B.X.)	50	40

The bank multiple arrangements of a final selector rack are determined by the volume of incoming traffic. Each 200-line final selector group must, of course, be considered as a separate unit, and the number of selectors to be provided per group can be calculated from a knowledge of the busy hour traffic incoming to 200 subscribers. In some cases 20 selectors will suffice to carry the traffic of a P.B.X. group serving residential lines. On the other hand, as many as 70 or more selectors may be required to carry the incoming traffic to a final selector group which serves a number of busy P.B.X. subscribers. Final selector groups of up to 50 banks are wired out as a complete multiple with one set of terminal strips. Very large final selector groups may extend over two racks. In such cases it is necessary to terminate the multiple on each rack and to provide a tie cable between the two sets of terminal strips.

Facilities are provided in every exchange for obtaining access to subscribers' lines for trunk offering and testing purposes. The normal method of obtaining such access is by the use of special final selectors located at the end of the normal final selector multiple. These trunk offering and test final selectors are distinguishable (Fig. 155) by the small size of the mounting.

Alarm Equipment Rack. All except very small automatic exchanges contain an alarm equipment rack. This rack (Fig. 156) accommodates all the common equipment associated with the exchange alarm scheme, impulse machines, meter pulse machines, voice-frequency generators, and so on. The alarm equipment rack is the central point for the distribution of all the exchange common services, e.g. ringing, tones, pulses, etc. The arrangements vary with the type and quantity of equipment required at any particular exchange. In Fig. 156 there is a rotary type impulse machine on the bottom shelf with regular and reserve meter pulse machines immediately above it. The relay sets on the two higher shelves are required for alarm delay conditions, for graduated howler, etc. The jackfield immediately above these provides a distribution and a localizing point for all the common services (tones, pulses, etc.), whilst the fuse panel at the top of the rack serves the P.B.X. power leads, ringing supply, positive battery distribution, and so forth. (The telephone receiver hanging on the right of the rack (Fig. 156) is required for checking the various tones, etc.)

Miscellaneous Apparatus Racks. In every exchange there is a large number of miscellaneous circuits which are not suitable for mounting as jacked-in relay sets. Some of these circuits have very few relays, whilst others, although larger, may have a large number of incoming and outgoing wires to other parts of the exchange. Apparatus of this type is usually "strip-mounted" on one or more racks designated "miscellaneous apparatus racks" (M.A.R.). Usually the miscellaneous apparatus racks are 2 ft 9 in. wide, and the apparatus

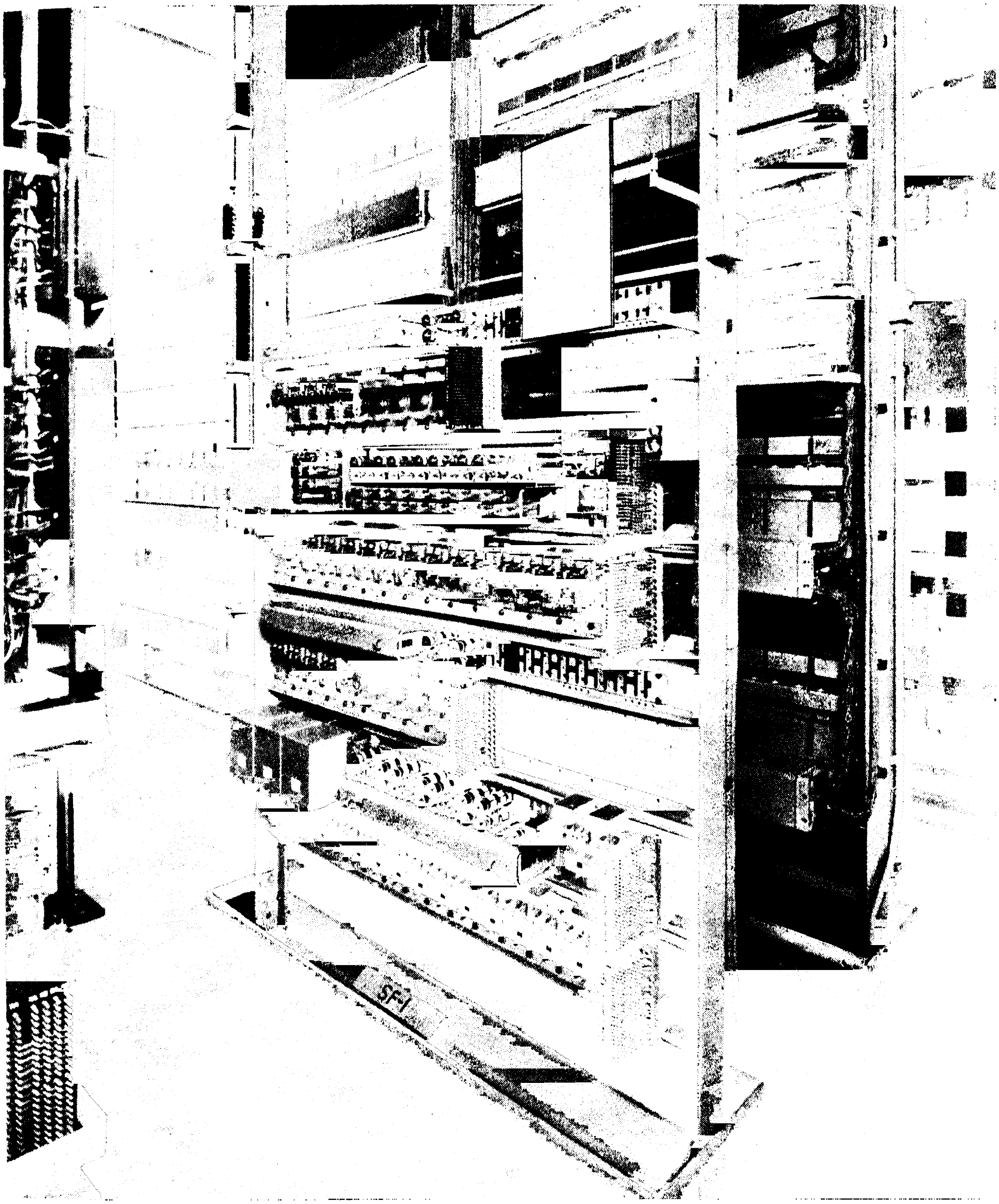


FIG. 153. SECONDARY FINDER RACK

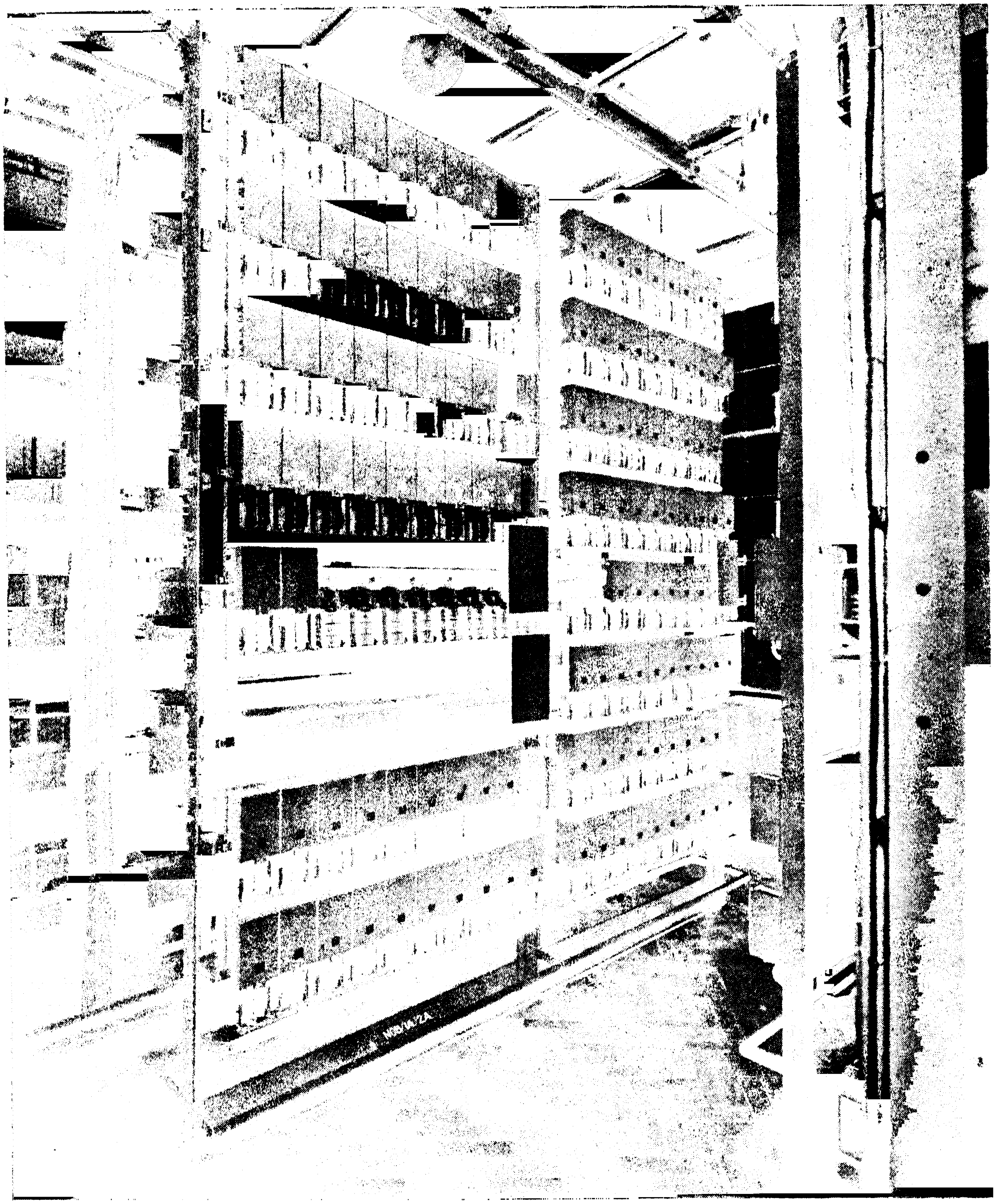


Fig. 154. Group Selector Racks

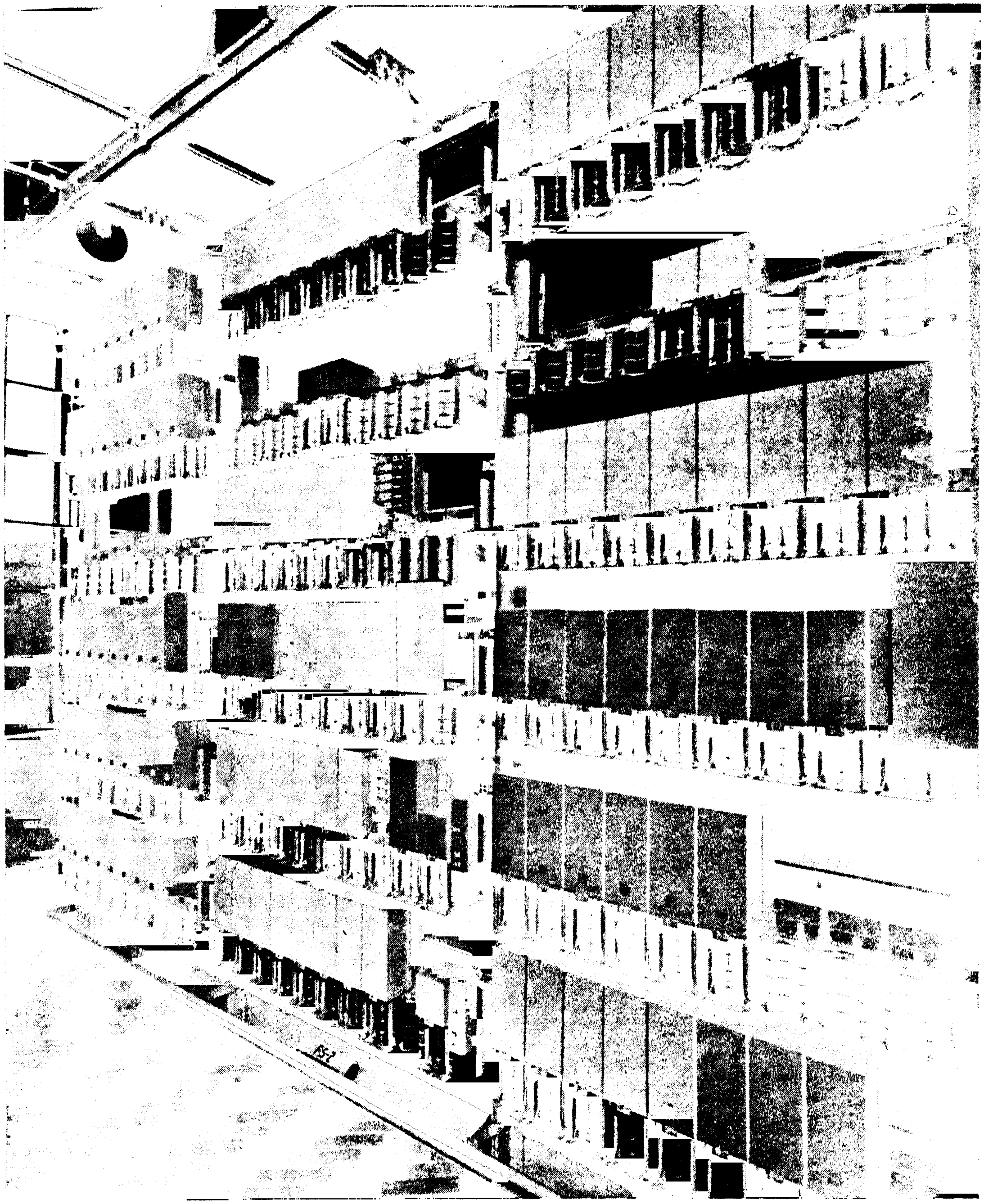


FIG. 155. FINAL SELECTOR RACKS

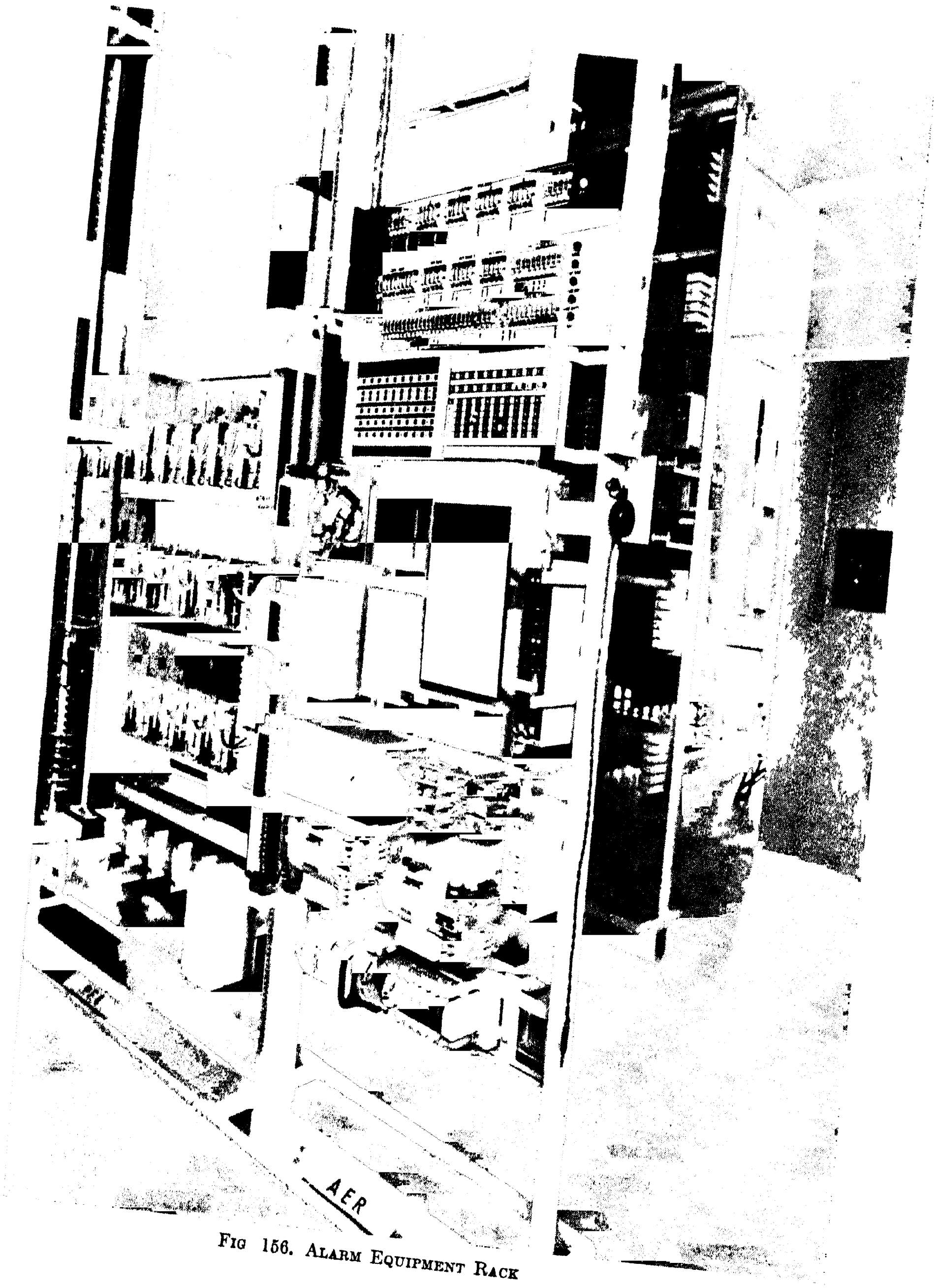


Fig 156. Alarm Equipment Rack

is mounted on plates which extend horizontally across the rack. Some plates are designed to cater for two rows of relays, whilst larger plates are available for the more complex circuits.

The circuits provided on the miscellaneous apparatus racks vary widely between different exchanges. They include a variety of equipment for the testing and plugging up of lines, various circuits required in connexion with the Test Desk, relays for night service switching, centralized service observation, and many other circuits of a similar miscellaneous character.

Other Racks. In addition to the main apparatus racks described in the previous paragraphs, equipment is also provided for measuring the flow of traffic through the exchange and for the routine testing of various parts of the main switching equipment. Such apparatus does not mix readily with other equipment, and is best accommodated on separate racks each having a distinct function. The racks are usually 1 ft 6 in. wide, i.e. three such racks occupy the same space as one standard 4 ft 6 in. rack.

Fig. 157 shows a rack of special equipment designed for the measurement of the traffic flow at the various points of the exchange. The rack adjacent is associated with it and accommodates certain uniselectors for obtaining access to the various selectors, etc., under test. The left-hand portion of Fig. 158 shows a routiner for the automatic testing of outgoing junctions, and its associated rack of uniselectors for obtaining access to the junctions. These particular racks are most conveniently erected near the I.D.F.

M.D.F. and I.D.F. Main and intermediate distribution frames of an automatic exchange follow the standard practice already described in Vol. I. As in a manual exchange, the subscribers' lines are terminated on fuse mountings on the line side of the M.D.F. The internal equipment is cabled to the protectors on the exchange side of the frame and the lines are connected as required to the equipment by means of "jumpers." With the normal exchange apparatus room (with a clear height of 12 ft) the M.D.F. has a capacity for 220 circuits per vertical on the line side, and 200 circuits per vertical on the equipment or exchange side. In all except the very small exchanges travelling ladders are provided on both sides of the frames. On very large frames a mezzanine platform is fitted to facilitate access to the circuits terminated on the upper part of the frame.

The right-hand portion of Fig. 158 shows a typical automatic exchange I.D.F. The terminal strips are mounted vertically on both sides of the frame, and each vertical normally accommodates 200 circuits. As in a manual exchange, the I.D.F. has two main functions: Firstly, it provides a point whereby the originated and incoming traffic can be distributed amongst the various uniselector, linefinder and incoming selector groups. Secondly, it provides a point for the interconnexion of apparatus. In an automatic exchange this second function is more important than in the manual case, and a much greater proportion of the I.D.F. is required for this purpose.

Inter-rack Cabling. The connexions between the various apparatus racks, frames, etc., of an automatic exchange are made by means of switchboard cable (see Volume I). Most of the circuits require three conductors (—, + and P-wires), and the switchboard cables are built up so that the speaking conductors are invariably arranged as a twisted pair.

On the apparatus rack itself, the incoming and outgoing cables are formed out on the brackets behind the selector or relay set shelves as shown in Figs. 144, 145 and 147. Bakelite blocks of special design (Fig. 159) are fixed to both the left- and right-hand upright members of the rack. The incoming and outgoing cables are neatly laced to these blocks and are then led to the main overhead cable runways of the exchange. (Figs. 148 and 154 clearly show the method of running the cables down the rack uprights.)

The cables between racks and between suites of racks are concentrated on a number of overhead cable racks. These racks are normally fixed to and supported by the inter-suite tie-bars. The cable racks should be located so that the load on the apparatus racks is distributed as evenly as possible. Care must be taken to ensure that the weight of the apparatus racks, and of the cable racks supported by them, does not in any case exceed the safe loading of the apparatus room floor. (The normal maximum load for automatic exchanges is 400 lb per foot run of apparatus rack.) If the load on the cable runways is too heavy to be supported on the racks, it is necessary to provide overhead support from subsidiary girders or from members fixed to the ceiling by means of expanded bolts. (In some cases dummy racks are installed to provide support for cable runways, etc.)

The overhead cable racks in an automatic exchange are almost invariably of the open "ladder" type. The racks are often made of strip iron with the cross pieces riveted or welded to the main side members. In recent years a number of ingenious forms of cable racking have been introduced with the object of simplifying the fabrication of the racks on site. Fig. 160 shows one such method. The side members are built up as required

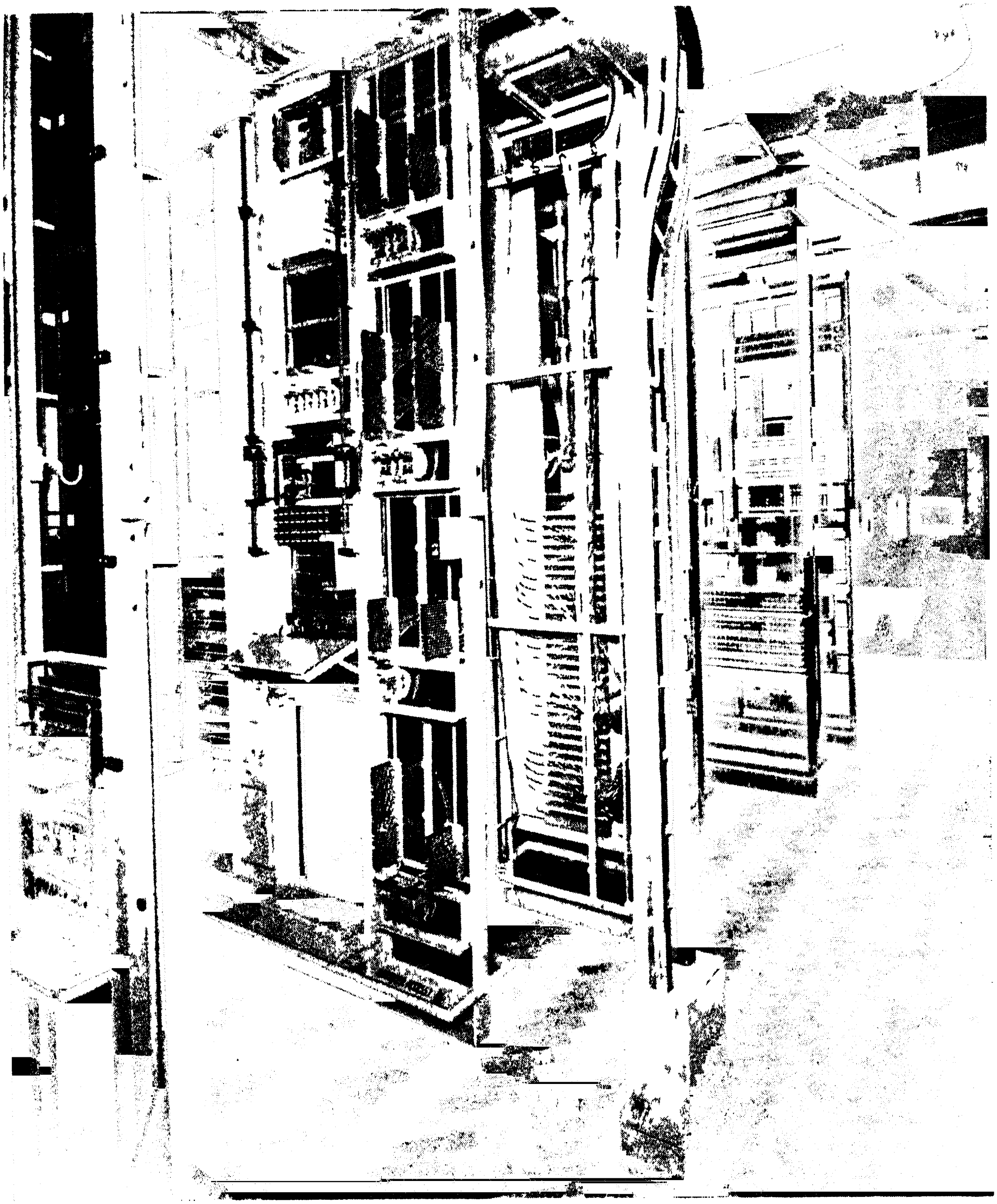


FIG. 157 TRAFFIC RECORDER AND ACCESS RACKS

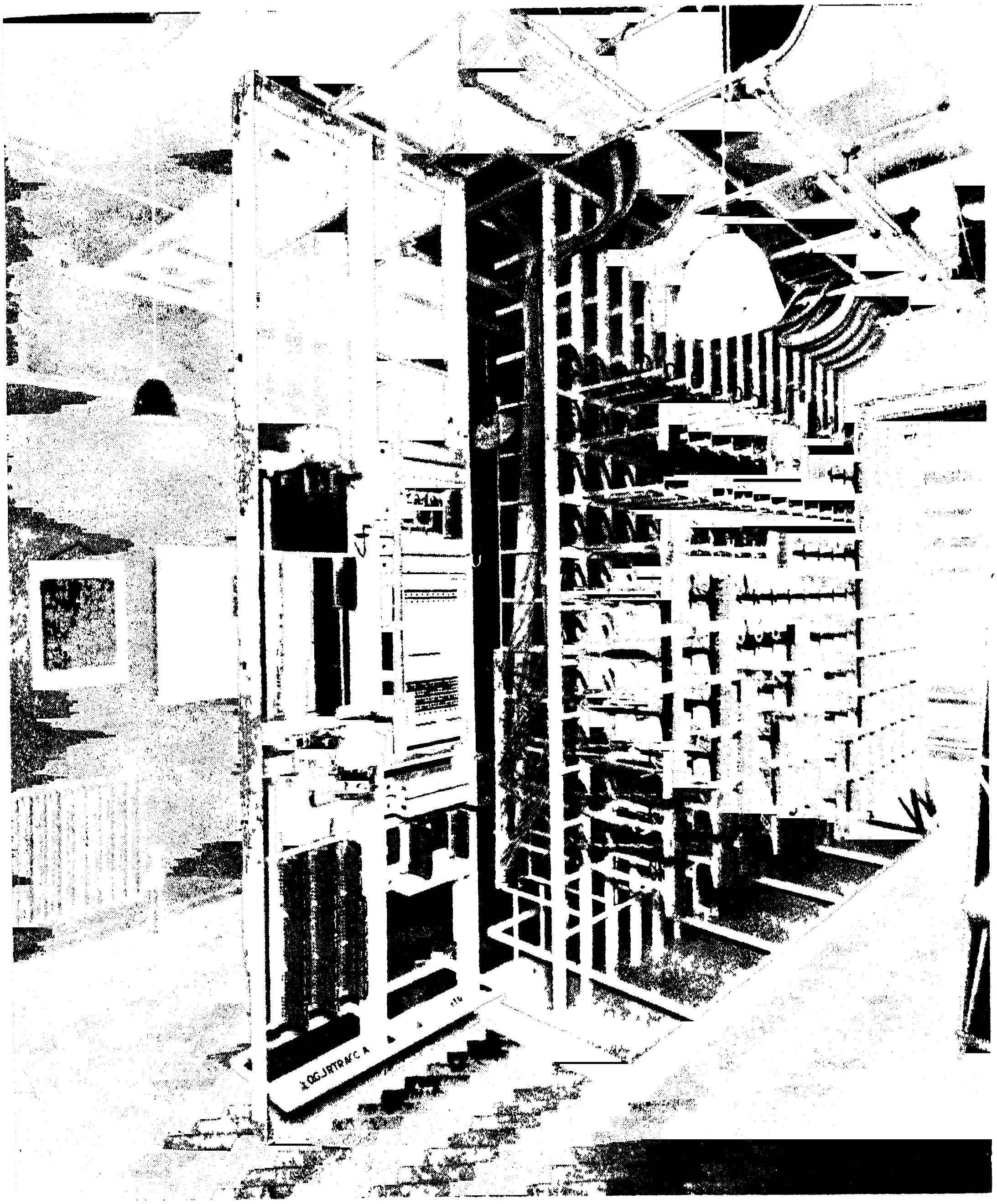


Fig. 158. I.D.F. and Outgoing Junction Routiner

from standard lengths of C-shaped rolled steel. The cross pieces are of similar, but smaller, cross-section and are clamped to the main side members by the use of small cast-iron blocks which are tapped to receive the fixing screw, and are designed to slide into the main side members. Simple

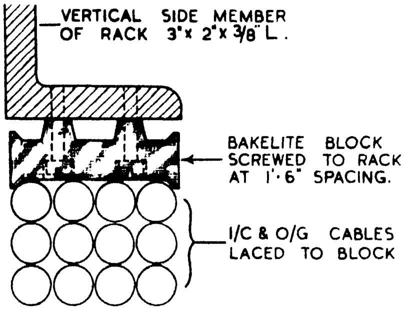


Fig. 159. Attachment of Cables to Rack Uprights

clamping plates, in conjunction with the same fixing blocks, are also used for connecting together consecutive lengths of racking. Various standard brackets make it possible to connect together two runways at right angles or at different levels. This form of construction provides a rack of good mechanical strength with a minimum of weight. There are no sharp edges on the cross members which would require protection where there is any change in the level of the cable run. The main purpose of the design is, however, to avoid the necessity for the drilling and bending of the rack material on site.

The cables are normally fixed to the cable rack by means of lacing twine. If the cable run passes from one floor to another, it is usual to protect the cables at the floor level by fitting a removable sheet iron shield some 12 in. high (see Fig. 157). When a cable run passes through a corridor or through other rooms, it is sometimes necessary to protect the cables from the varying humidity conditions. This protection is normally provided by sheet iron covers which completely enclose the cable rack.

In all cases where a cable runway passes from one room to another the hole is sealed with a fire-resisting material (see Volume I).

Grading of Trunks between Selectors. In the British standard system the outlets from one rank of selectors are graded to the next rank of selectors wherever it is not possible to provide full availability. The theoretical aspects of grading have already been considered in some detail in Chapter II. From a cabling point of view, the adoption of grading necessitates:

(*a*) Facilities for commoning together the later choice outlets.

(*b*) A means of connecting each individual or commoned trunk to a selector of the next rank.

(*c*) Facilities for rearranging the commoning and the allocation of selectors to the various trunks to meet changing conditions during the life of the exchange.

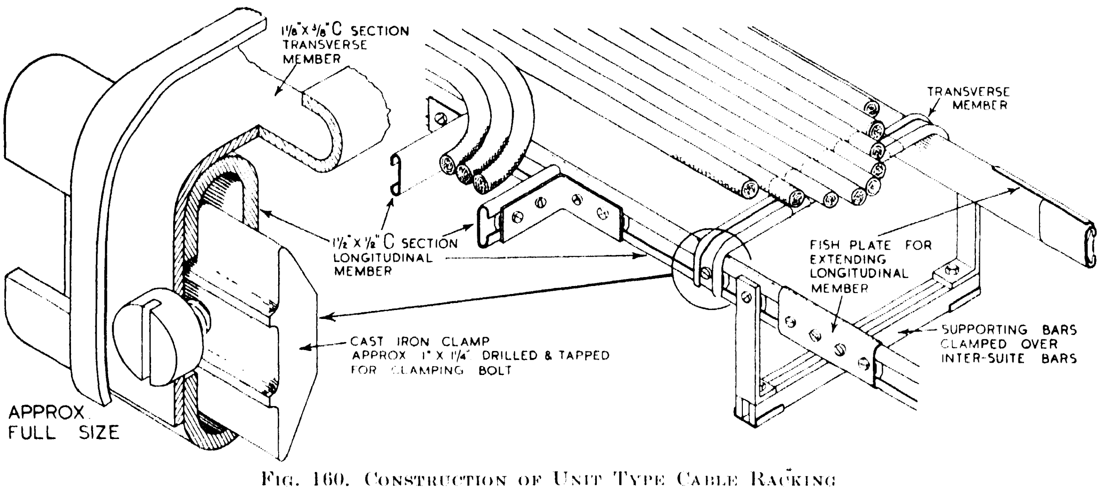


Fig. 160. Construction of Unit Type Cable Racking

There are several methods of grading the outlets from one rank of switches to the selectors of the next switching stage. In some of these methods the commoning of the outlets is carried out on the selector rack or on the I.D.F., but in other schemes special frames, known as *Trunk Distribution Frames* (T.D.F.), are provided. The various methods can be broadly classified under three main headings:

1. *Centralized Grading.* With this scheme the selector multiples are cabled out to a centralized frame which serves the whole exchange. Sufficient cables are led out to this point to provide the required number of "grading groups." At the trunk distribution frame these cables are connected to terminal strips in such a way that the outlets of the various multiples can be readily commoned. The incoming cables of each rank of selectors are also terminated at the centralized frame so that any outlet can be cross-connected to any desired selector by means of a simple system of jumpering. The concentration of all outgoing and incoming trunks on one centralized distribution frame provides a scheme which gives a very high degree of flexibility. Any outlet from any selector can be connected to any other selector (irrespective of rank) in the exchange. Similarly, any outlet of any switching stage can be connected to an external circuit by the provision of a common group of tie-circuits between the distribution frame and the exchange I.D.F. The flexibility of the scheme can be still further enhanced by incorporating the distribution frame in the main I.D.F. of the exchange, thereby eliminating the necessity for tie-circuits. On the other hand, the provision of a centralized T.D.F. requires the cabling of a large number of separate multiples to a common point which may be some distance from a number of the selector racks, and hence the scheme is somewhat costly from a cabling point of view.

2. *Sectionalized Grading.* Some reduction in the cabling costs can be obtained by providing a number of "sectional" Trunk Distribution Frames located at suitable points in the exchange. For example, a separate trunk distribution frame could be provided for the grading of uniselector outlets to 1st selectors. This frame should be so located that the overall cabling costs are a minimum. A second trunk distribution frame can now be provided at another point in the exchange for the grading of the trunks between 1st and 2nd selectors, whilst a third frame can serve as an interconnecting point between 2nd selectors and final selectors. In a large exchange it may even be advantageous to provide two or more separate distribution frames for each switching stage, e.g. there may be two or three separate T.D.F.s, each frame serving a portion of the subscribers' uniselector racks. The sectionalizing of the trunk distribution arrangements does, of course, involve the provision of a number of separate groups of tie-circuits between each T.D.F. and the I.D.F., and sometimes from one T.D.F. to another. The number of tie-circuits is, however, relatively small compared with the number of circuits from the bank multiples. Moreover, the sectionalizing of the trunk distribution arrangements produces a number of separate T.D.F.s, each with comparatively straightforward cross-connexions as compared with the somewhat complex jumpering field at a centralized frame. Modern practice favours the use of sectionalized T.D.F.s rather than the centralized scheme.

3. *Grading on Racks.* The cabling costs of an exchange can be still further reduced if arrangements can be made for grading the various bank multiples on the selector racks themselves. By suitable arrangements, it is possible to terminate the bank multiple wiring on the terminal strips behind the selector shelves in such a way that outlets can be commoned as required by simple straps between adjacent terminals. Most gradings in practice require the commoning of multiples which may be spread over a number of selector racks. If the grading is carried out behind each individual rack, then it becomes necessary to provide inter-rack tie cables. Similarly, if extensive rack-to-rack jumpering is to be avoided, it is also necessary to subdivide the outgoing circuits into a number of separate groups, each group providing the outgoing trunks for the portion of the grading appearing on one particular rack. It is, moreover, difficult to obtain a complete picture of the grading arrangements when the commoning is spread over a number of connexion strips which are located behind different selector racks. On the other hand, a rack grading scheme is generally much more flexible than any scheme which involves the cabling out of the various bank multiples to sectional or centralized grading points.

With the two latter schemes, very careful design is required in order to provide sufficient grading groups to give a reasonable degree of flexibility, but at the same time to minimize the cost of cabling to the grading point. In any particular case the arrangements adopted must be a compromise. If, however, the grading is carried out behind the selector racks, a large number of separate multiples can be wired out to the grading point with little or no additional expense. It is in fact readily possible to terminate each shelf (or pair of shelves) separately, and to build up the required grading groups by commoning these basic multiples to meet the changing needs of the exchange.

Trunk Distribution Frames. Fig. 161 shows the construction of a typical trunk distribution frame. The frame is designed to line up with the standard apparatus racks, and can be used en suite with the selector racks to provide a sectionalized grading scheme or, alternatively, a number of unit frames can be formed into a separate centralized grading

frame. The cables from the various selector multiples are led down the space provided for this purpose on the right-hand portion of the frame (as seen from the front). The front of this vertical cable run is covered with sheet iron, which gives protection to the incoming cables, and also provides space for the signwriting of the incoming multiple designations (i.e. details of the racks and shelves served by each incoming cable).

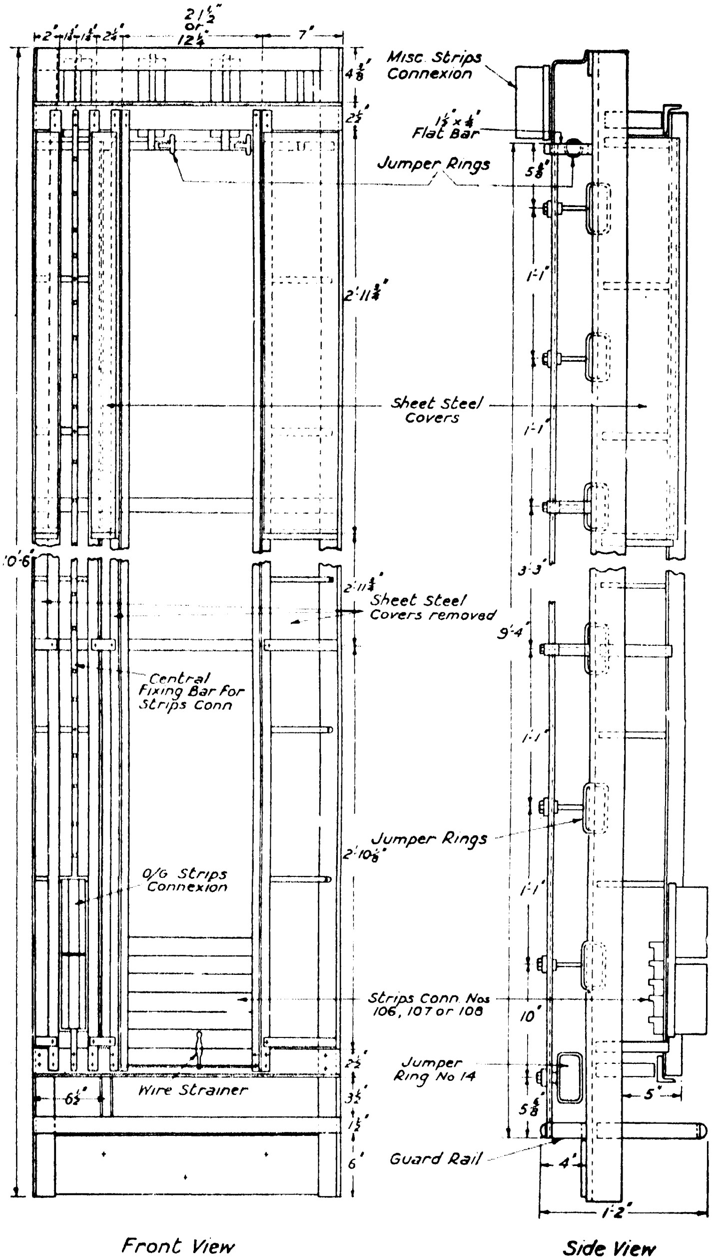


Fig. 161. Construction of Trunk Distribution Frame

The central part of the frame provides accommodation for a number of terminal strips of a type specially designed to facilitate the commoning of the various incoming groups. The incoming cables are formed out behind these terminal strips, each strip serving the —, + and P-wires of a 20- or 24-circuit multiple. When the T.D.F. is required for the grading out of uniselector banks, each terminal strip has 24 groups each of 3 terminals to serve the 24 outlets from the uniselectors. If, on the other hand, the grading serves a group selector level, then only 20-point terminal strips are required to serve the 20 outlets of that level. The terminal strips required for uniselector gradings are naturally somewhat wider than those used for group selector gradings. Trunk distribution frames have therefore been designed in two sizes (3 ft 0¼ in. wide, and 2 ft 3 in. wide) to cater for the two conditions. A 10 ft 6½ in. frame has a capacity for 64 incoming strips.

The outgoing cables to the I.D.F. and to the next selector stage are fed down the left-hand portion of the trunk distribution frame, and are terminated on ordinary type connexion strips as shown in Fig. 161. There is a capacity for 16 such connexion strips in one vertical line (i.e. with 40 outgoing circuits per connexion strip, the frame will accommodate 640 outgoing circuits).

The separate outlets of the various incoming groups can be commoned together by means of bare tinned copper straps between the terminals as shown in Fig. 162. The ends of the connexion tags are specially forked to take the vertical straps or grading wires, which are soldered to the tags as required. The trunks from the grading commons are connected to the required outgoing circuits by means of 3-wire jumpers. These jumpers are connected to the uppermost tags of the commoning and then passed through holes in the connexion strip and through the various jumper rings behind the frame before being terminated on the outgoing connexion strips. The whole design provides for a neat and orderly arrangement of jumpers and commoning wires

which can easily be rearranged at any time during the life of the exchange.

Fig. 163 shows the arrangements at a trunk dis-

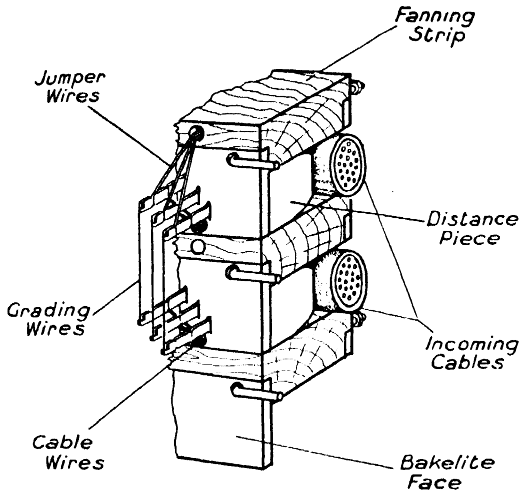


FIG. 162. METHOD OF COMMONING OUTLETS ON GRADING STRIPS

tribution frame to give a 4-group grading to 20 2nd selectors from 3 racks of 1st selectors. For simplicity the availability has been restricted to 10, and typical jumpers only have been shown. In this particular case it is assumed that each grading group serves the 1st selector multiple of 6 shelves (i.e. each grading group takes the traffic from 60 1st selectors). The various shelves of each group are multipled together at the selector rack, and one cable is led to the T.D.F. from each group of shelves. Individual trunks are allocated to the first 2 choices of each group in the grading whereas, the next 4 choices are "paired." The last 4 choices are commoned throughout, i.e. each late-choice outlet is served by a single 2nd selector.

Grading on Racks. The use of sectional or centralized trunk distribution frames as described above, necessitates a careful study of the requirements at each exchange to determine the best grouping of the trunks from each rank of selectors. At the best, the number of groups brought out to each grading point must be a compromise between the initial and the ultimate requirements. In some cases the calling rate changes materially during the life of an exchange, and the grading groups brought out to the T.D.F. may require modification during the life of the exchange. Such modifications cannot be made without interfering with the permanent cabling. The use of the T.D.F. scheme also necessitates a considerable amount of individual engineering work for each exchange, i.e. the multipling of the selector shelves and the number of cables to the T.D.F. varies with each particular exchange.

There are some advantages in having a standard selector rack with a uniform system of bank multiples which can be commoned or graded as required at the rear of the rack. This scheme requires the provision of tie-circuits between the rack and some point (usually the I.D.F.) where connexion can be made to the next switching stage. Moreover, the traffic from a number of racks is often combined into one grading, and hence tie cables are

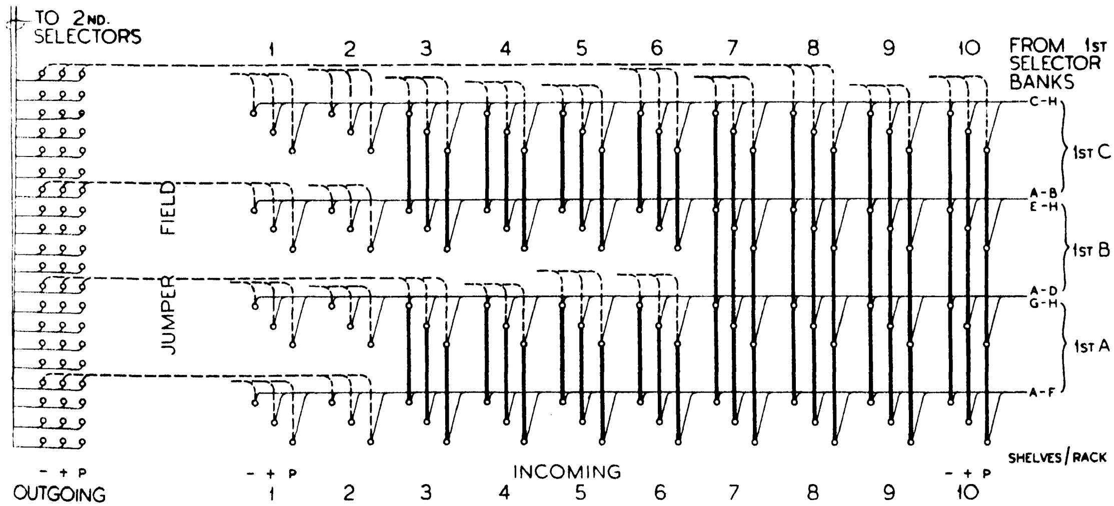


FIG. 163. TYPICAL COMMONING AND JUMPERING ARRANGEMENTS AT A T.D.F.

required between all the racks of one switching stage. Such inter-rack cabling must be arranged to give full flexibility. One disadvantage of a rack

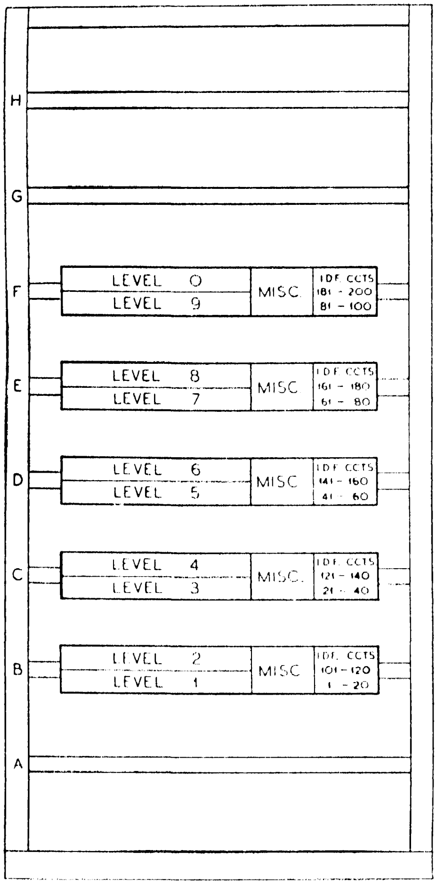


FIG. 164. ARRANGEMENT OF TERMINAL STRIPS BEHIND GROUP SELECTOR RACK WITH GRADING FACILITIES

grading scheme is that the grading is split over a number of separate apparatus racks, so that it is not possible to get a clear picture of the full grading at any one point. This difficulty is not serious, since the grading arrangements can readily be shown on a grading chart.

It has recently been decided to abandon the use of T.D.F.s for the grading between group selector stages. The new scheme is based upon a standard fully wired group selector rack, the bank multiples of which are terminated on a series of connexion strips behind the rack. The basic rack is the same for all exchanges and can be manufactured in bulk. A considerable degree of standardization has also been achieved in the number and arrangement of the tie-circuits between racks and from the racks to the I.D.F.

Fig. 164 shows the general arrangements behind the standard group selector rack. Each rack is equipped with 8 shelves, each of 10 selectors. Connexion strips are provided on 5 of these shelves, and the bank wiring is terminated on the connexion strips in such a way that corresponding levels of each pair of shelves are terminated on adjacent terminals. Fig. 165 shows the detailed layout of the terminations. The connexion strips behind each shelf provide the terminations for two adjacent levels, e.g. levels 1 and 2. Shelves A and B are provided with a continuous multiple, which is terminated on the bottom row of terminals. Similarly, the multiple from shelves C and D is terminated on the row of terminals immediately above, whilst shelves E, F and G, H are similarly terminated. A further row of terminals provides 20 tie-circuits per level to the next group selector rack. The tie-circuits to the I.D.F. are terminated on a connexion strip mounted alongside the multiple terminations. The shelf multiples can be commoned together or graded as required by the use of bare tinned copper vertical straps on the grading strips, and any circuit can be connected to the I.D.F. by means of a jumper between the grading strip and the I.D.F. tie-circuit connexion strip.

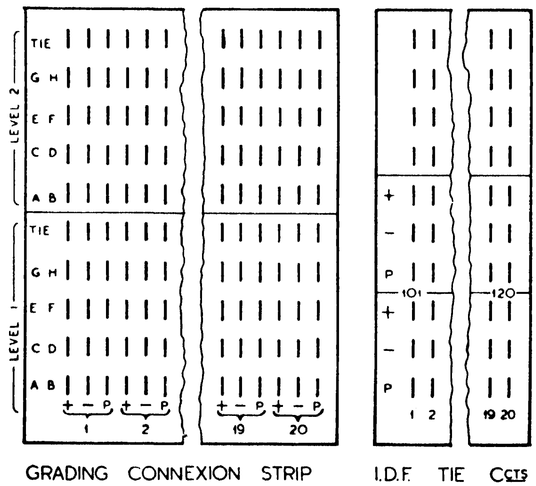


FIG. 165. ARRANGEMENT OF TERMINALS ON CONNEXION STRIPS

Fig. 166 shows a typical arrangement. For simplicity the grading has been restricted to 3 racks, and the grading arrangements for one level only have been shown. The shelves of each rack are arranged in pairs (AB, CD, EF and GH) and each pair of shelves is wired out to a horizontal row of

terminals on the grading strip of the appropriate level. The tie cable is terminated at one end on an individual row of terminals, and at the other is two pairs of shelves. Later choices are progressively commoned to more and more shelves until the full commons are reached on the later choices. Fig. 167

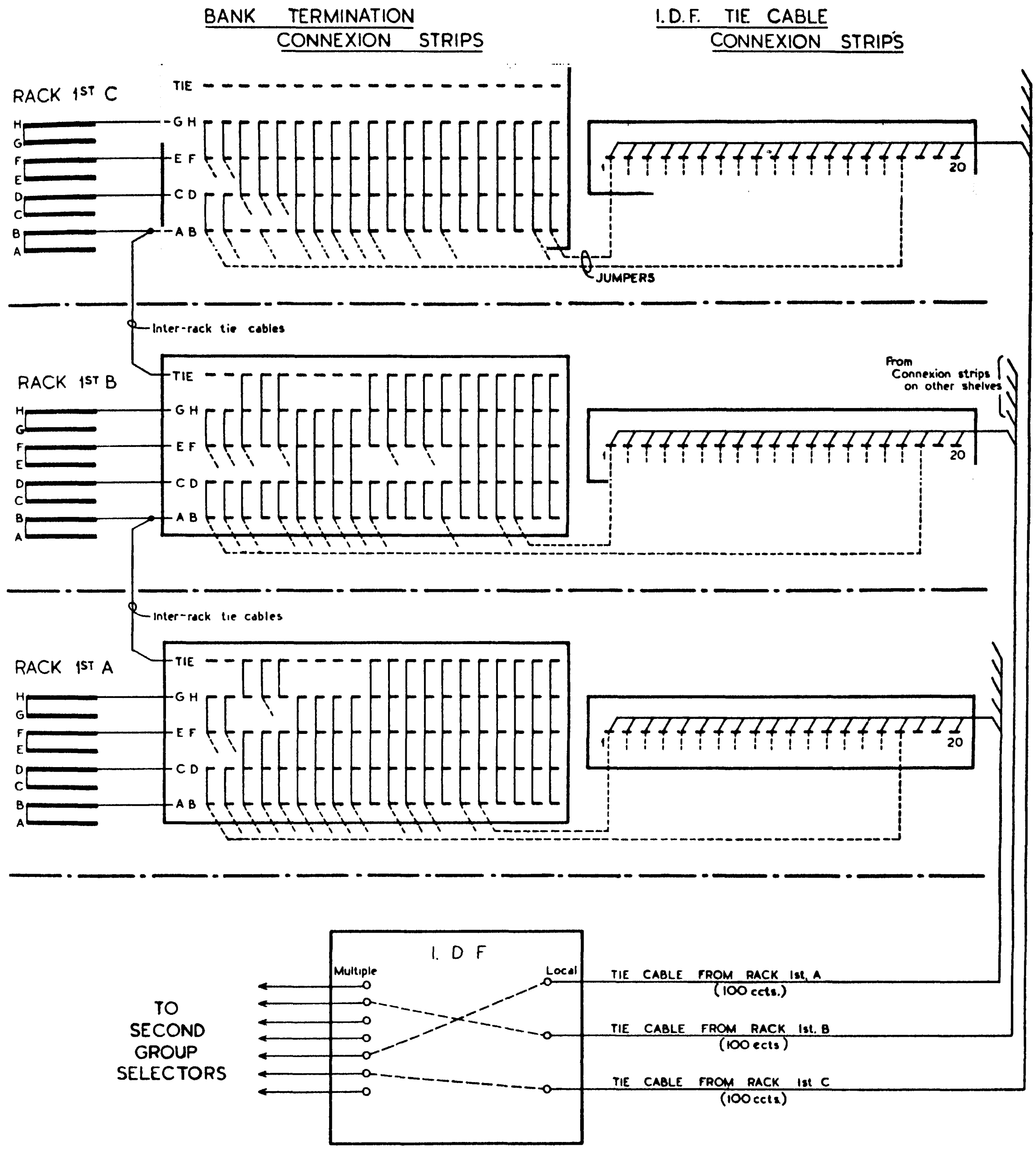


Fig. 166. Typical Grading Arrangement on a Group Selector Rack

connected to the row of terminals serving the A and B shelves of the next rack. In the example shown, the strappings are arranged to provide a 12-group grading scheme with the first choice common to shows the theoretical arrangements of the full grading.

A jumper is required between the grading strips and the I.D.F. tie cable strips for each common of

the grading. In the interests of standardization, it has been decided to provide a uniform number of circuits from each rack to the I.D.F. 100 circuits

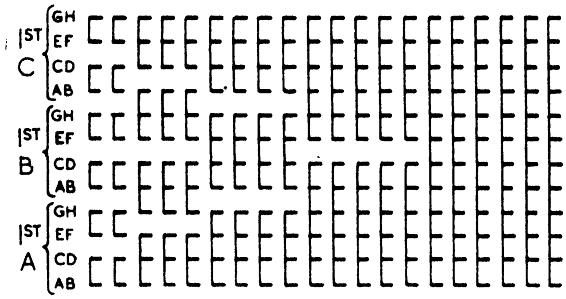


Fig. 167. 12-group Grading Provided by the Strapping Arrangements of Fig. 166

are provided between 1st group selector racks and the I.D.F., whilst 200 circuits are provided in all cases for 2nd and subsequent group selector racks. The tie-circuits are equally distributed over the five shelves of each rack (i.e. a 1st group selector rack has 20 tie-circuits on each shelf). By distributing the jumpers over all the racks in the grading, it is usually possible to connect the I.D.F. tie-circuits to the grading points by means of short horizontal jumpers along the back of the shelf. Facilities are, however, provided for jumpering between the grading strips on one shelf, and the I.D.F. cable terminations on the other shelves of the rack.

Fig. 168 gives a general view of the bank multiples and the terminal strips behind a group selector rack with grading facilities. (The dust covers have been removed.) Fig. 169 shows a cross-section of one shelf and indicates the general location of the various cables and wiring forms. The terminal strip mounting bracket is of special design to facilitate jumpering, and is designed to accommodate the metal designation strip for the tag markings. It will be noted from Fig. 168 that some of the inter-shelf cable forms occupy the space behind the 2 in. flange of the rack upright member which is normally reserved for the incoming and outgoing cables (see Fig. 159). This necessitates the provision of a special cable bracket for the incoming and outgoing cables. A jumper ring is attached to the cable brackets on the right-hand upright to allow for jumpering between shelves.

Trunking Charts. A series of charts is prepared for every automatic exchange to facilitate the tracing of calls from stage to stage. The charts are placed in glass-fronted notice frames located on the rack to which they refer. Generally speaking, every apparatus rack is provided with trunking charts which will enable a call to be readily traced either forwards to the next switching stage, or backwards to the previous stage. In addition to their main purpose of facilitating the tracing of calls, the trunking charts also provide a complete record of the trunking scheme of the exchange and are invaluable for the planning of any rearrangements or alterations to the main trunking scheme.

Fig. 170 shows a typical trunking chart on a subscribers' uniselector rack. It indicates the designation (rack letter, shelf letter and switch

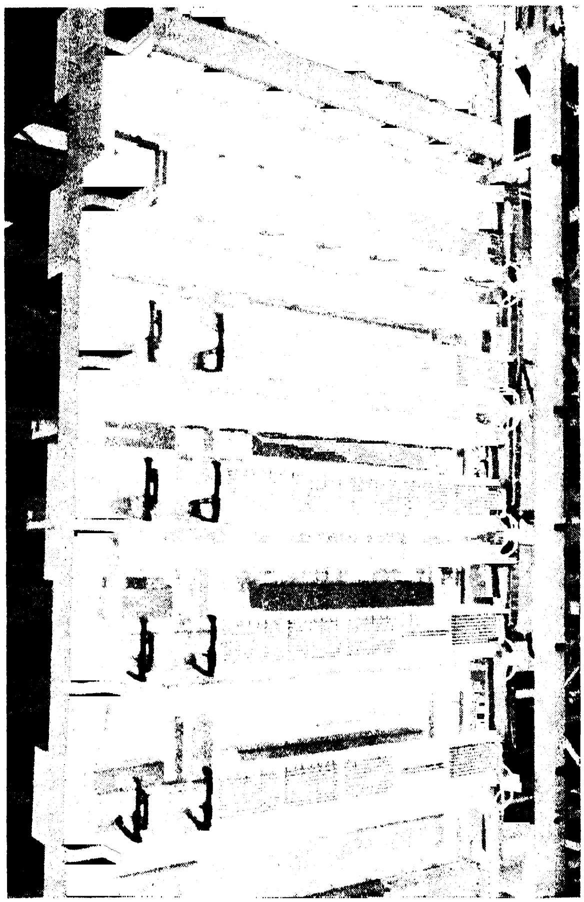


Fig. 168. Part Rear View of Group Selector Rack with Grading Facilities

number) of the 1st selector which is accessible from every outlet of each shelf of uniselectors. In most cases a selector is common to a number of shelves of the uniselector rack and, in order to avoid confusion, it is usual to show the selector reference only at the start and finish of the commoning (e.g. in

Fig. 170, 1st selector *BA*1 is accessible from the first outlet of shelves E to K inclusive).

A chart is provided on each 1st selector rack to show how the outlets from the uniselector racks are graded to 1st selectors. A typical example is shown in Fig. 171. The chart gives details of the uniselector rack and shelf numbers and of the grading arrangements to the various 1st selectors.

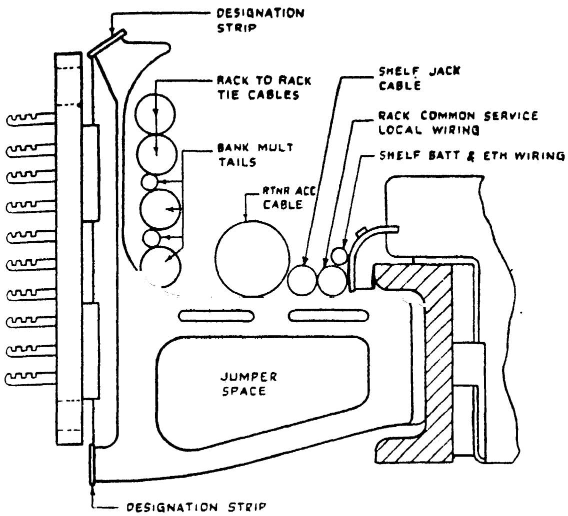


Fig. 169. End View of Group Selector Shelf

chart is provided on every 1st selector rack to show the allocations of the 1st selector levels.

Similar charts are provided on intermediate selector racks and on final selector racks, the design of the charts differing slightly to meet the particular conditions of use.

In order to facilitate the tracing of faults, the charts on racks with grading facilities (Fig. 166) are arranged to show the points from which the jumpers are taken, and also the number of the I.D.F. tie-circuit utilized for every outgoing trunk. Fig. 172 shows a small portion of a typical grading chart. The oblique lines show the points from which jumpers are taken and the associated numbers give the I.D.F. tie-circuit designation.

Cabling Scheme Using T.D.F.s. Fig. 173 shows the main cabling arrangements of a 4-digit non-director exchange where trunk distribution frames are used for the interconnexion of the various switching stages. The underground cable pairs are terminated in geographical order on the line side of the M.D.F. From this point they are connected by means of 2-wire jumpers to the appropriate numbers on the exchange side of the frame. Each vertical on the exchange side of the M.D.F. accommodates 200 circuits arranged in strict numerical order, and these circuits are cabled to the multiple side of the I.D.F. Any individual number can be cross-connected to any desired calling equipment by means of a jumper to the local side of the I.D.F.

	SHELF	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
	K	BA1	CB2	DC3	BC5	AA6	DA6	AA7	DC7	AB8	CB8	DC8	AC9	BC9	DA9	DC9	AB10	AC10	BC10	CA10	CB10	CC10	DA10	DB10	DC10
	J																								
U. S.	H																								
RACK	G																								
No. 3.	F																								
	E	BA1	CB2	DC3																					
	D	AC1	CA2	DB3																					
	C																								
	B																								
	A	AC1	CA2	DB3	BC5	AA6	DA6	AA7	DC7	AB8	CB8	DC8	AC9	BC9	DA9	DC9	AB10	AC10	BC10	CA10	CB10	CC10	DA10	DB10	DC10

Fig. 170. Typical Trunking Chart Provided on Subscribers' Uniselector Rack

(E.g. the second group of the grading shown in Fig. 171 is accessible from the uniselectors on shelves J and K of uniselector rack No. 1, plus shelves A to F of uniselector rack No. 2. The chart also shows that the cables from these uniselector racks are taken off from shelf A of No. 2 uniselector rack.) In addition to the uniselector grading, a

This extends the line to a particular subscriber's uniselector. The bank multiple of each shelf of uniselectors is terminated on a connexion strip at the end of the shelf. Depending upon the calling rate, a number of shelves are multipled together by means of inter-shelf tie cables to form one grading group. The multiple from this group is

now extended to the subscribers' uniselector T.D.F. The various other grading groups are similarly terminated on this T.D.F. and are graded by means of bare vertical wires. Jumpers are taken from the grading at the appropriate points this point it is usual to provide outgoing circuits to the next group selector stage and also tie-circuits back to the I.D.F. for outgoing junction routes. The cabling arrangements of the 2nd and subsequent group selector stages are similar, tie-

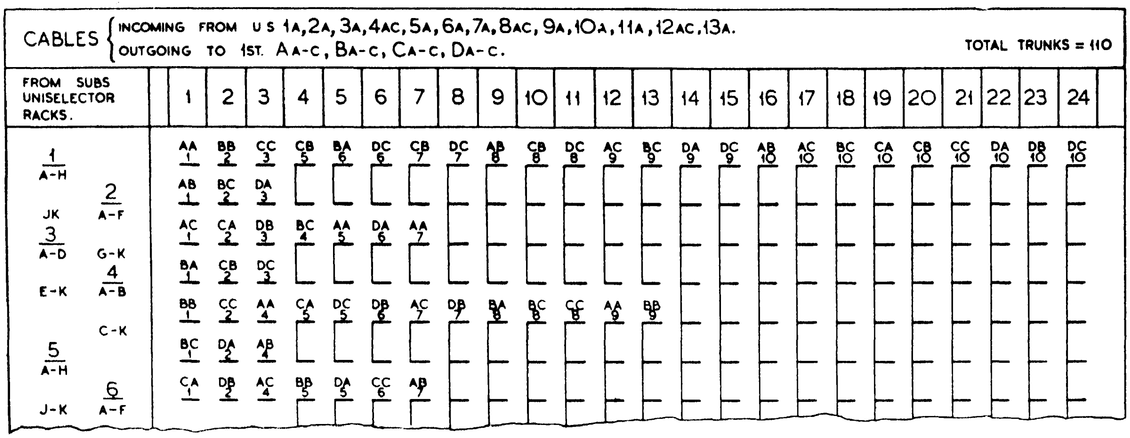


FIG. 171. TRUNKING CHART ON 1ST SELECTOR RACK

to a connexion strip which is cabled to the incoming side of the 1st group selectors.

The bank multiple of the 1st group selectors is continuous over one, two or more shelves as called for in the equipment specification, and the multiple is terminated on a row of connexion strips behind one of the shelves. Tie cables may be provided between several group selector multiples to provide a grading group which is cabled out to the T.D.F. Here again, the various groups of trunks from the 1st selector levels are graded and commoned as required, and the outgoing trunks from the grading are jumpered to an outgoing connexion strip. At

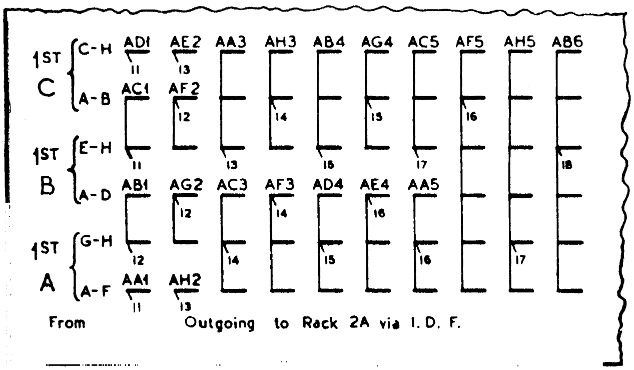


FIG. 172. TRUNKING CHART ON GROUP SELECTOR RACKS WITH GRADING FACILITIES
(Showing jumpering points and I.D.F. tie-circuit numbers)

circuits to the I.D.F. being provided at each stage for outgoing junction circuits. The final selector multiple is continuous over a number of shelves, depending upon the volume of traffic to the particular final selector group. (A final selector group may range from 10 to 40 or more banks.) Each multiple is terminated on connexion strips at the rear of the rack, from where the circuits are cabled to the I.D.F. The circuits from ordinary and 2/10 P.B.X. final selectors are terminated on the multiple side of the I.D.F. on the same tags as the M.D.F. tie-circuits. The subscribers' meters are also terminated at the same point on the multiple side of the I.D.F.

In order to conserve the numbers of the exchange numbering scheme, it is usual to allocate numbers outside the normal range for the lines in large P.B.X. groups. A special group of tie-circuits between the M.D.F. and the I.D.F. is provided for such lines, and the meters are arranged as a number of large groups, as called for in the equipment specification. The bank multiples of 11 and over type P.B.X. final selectors are terminated on the local side of the I.D.F., from which point they can be jumpered as desired to any line in the special group of M.D.F. circuits.

Cabling of Linefinder Exchanges. Fig. 174 gives the general cabling scheme of an exchange with a partial secondary linefinder scheme. The subscribers' line relays are wired to the local side of the I.D.F. where they can be cross-jumpered as

required to any desired multiple number. The line relays are connected by direct cabling to the primary finder racks, and the linefinders themselves are led out to the multiple side of the I.D.F. From this point it is possible to jumper either direct to the 1st selectors (for directly-connected linefinders) or, alternatively, to the I.D.F. terminations of the secondary finders.

The cabling of the group and final selectors is exactly the same as for a uniselector type exchange, and is as indicated in Figs. 173 or 175.

from the multiple to the local side of the I.D.F. Fig. 175 also shows the standard number of circuits between the selector racks and the I.D.F. It is found that 100 circuits meet the requirements from 1st selector racks and leave an adequate margin even in difficult cases. The 2nd and subsequent selector racks require a somewhat greater number of outgoing circuits to the I.D.F. owing to the greater number of levels usually in use.

With a cabling scheme as shown in Fig. 175 the I.D.F. can be considered as comprising two distinct

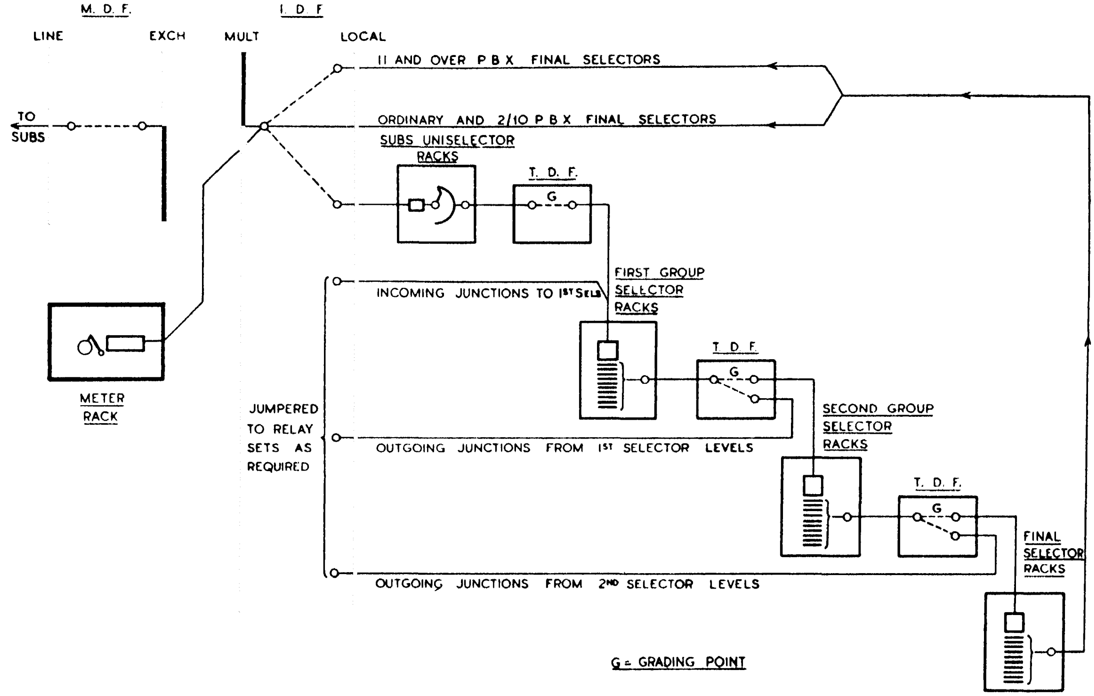


FIG. 173. CABLING SCHEME OF 4-DIGIT EXCHANGE WITH SUBSCRIBERS' UNISELECTORS
(Utilizing Trunk Distribution Frames throughout)

Cabling Scheme with Grading on Group Selector Racks. Fig. 175 shows the basic cabling arrangements of a new exchange which is equipped with group selector racks having grading facilities. The multiples from the subscribers' uniselector racks are terminated as before on a T.D.F. of standard design. The outlets are graded at this point, and are jumpered to tie-circuits which terminate on the local side of the I.D.F. The incoming lines to each group selector stage are cabled from the multiple side of the I.D.F., whilst the graded outlets from the banks are taken to the local side of the I.D.F. It is usually possible to cross-connect any outgoing trunk from one selector stage to the incoming side of a selector of the next stage by a simple jumper

portions. The first (which might be designated the subscribers' I.D.F.) provides for the interconnecting of the subscribers' calling equipment with the final selector multiple numbers. The second portion (which could be designated the equipment I.D.F.) is concerned entirely with the interconnexion of the various switching stages. Both portions of the I.D.F. can be combined on one common frame or, if necessary, the two portions of the I.D.F. can be separated to facilitate cabling or to improve the lay-out of the exchange.

Interconnexion of Junctions and Manual Board Circuits. Fig. 176 shows typical examples of the cabling and cross-connexion arrangements for incoming and outgoing junctions terminated either

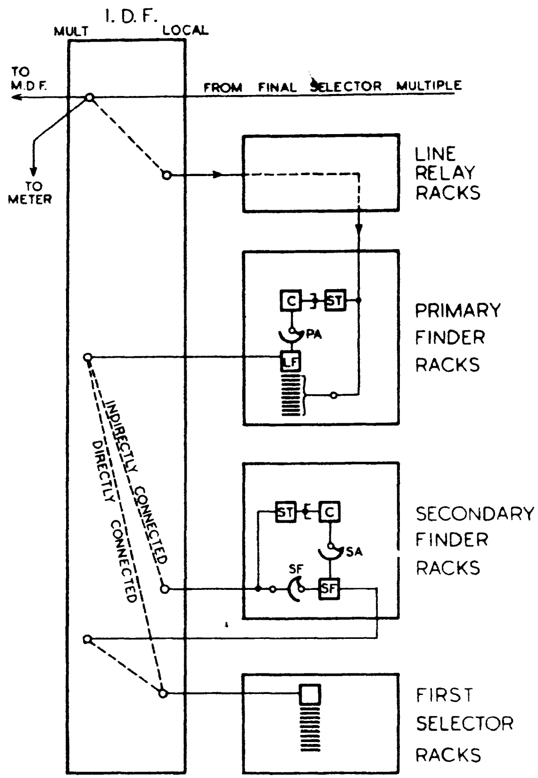


Fig. 174. Cabling of Linefinder Equipment Racks

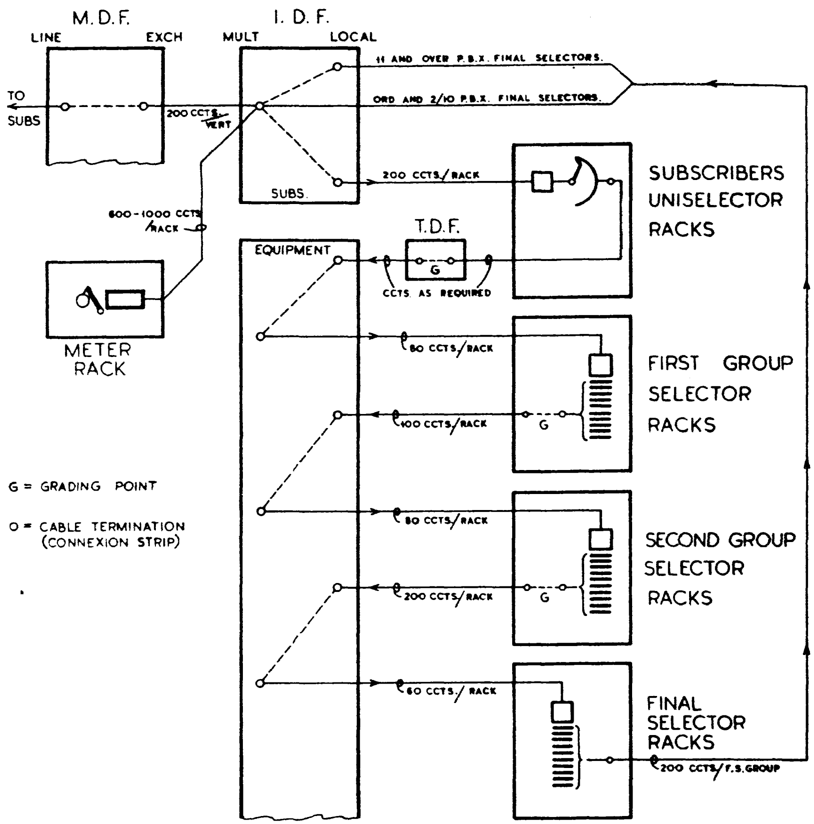


Fig. 175. Cabling Scheme of 4-digit Exchange With Subscribers' Uniselectors
(Grading on group selector racks)

on selectors or on the automanual switchboard. The junction circuits are extended from the M.D.F. to the I.D.F. by means of three common groups of circuits. The first group terminates on the local on the manual switchboard. This group also caters for any outgoing junctions which are not routed through the test jack frame. The third group of circuits is connected between the exchange side of

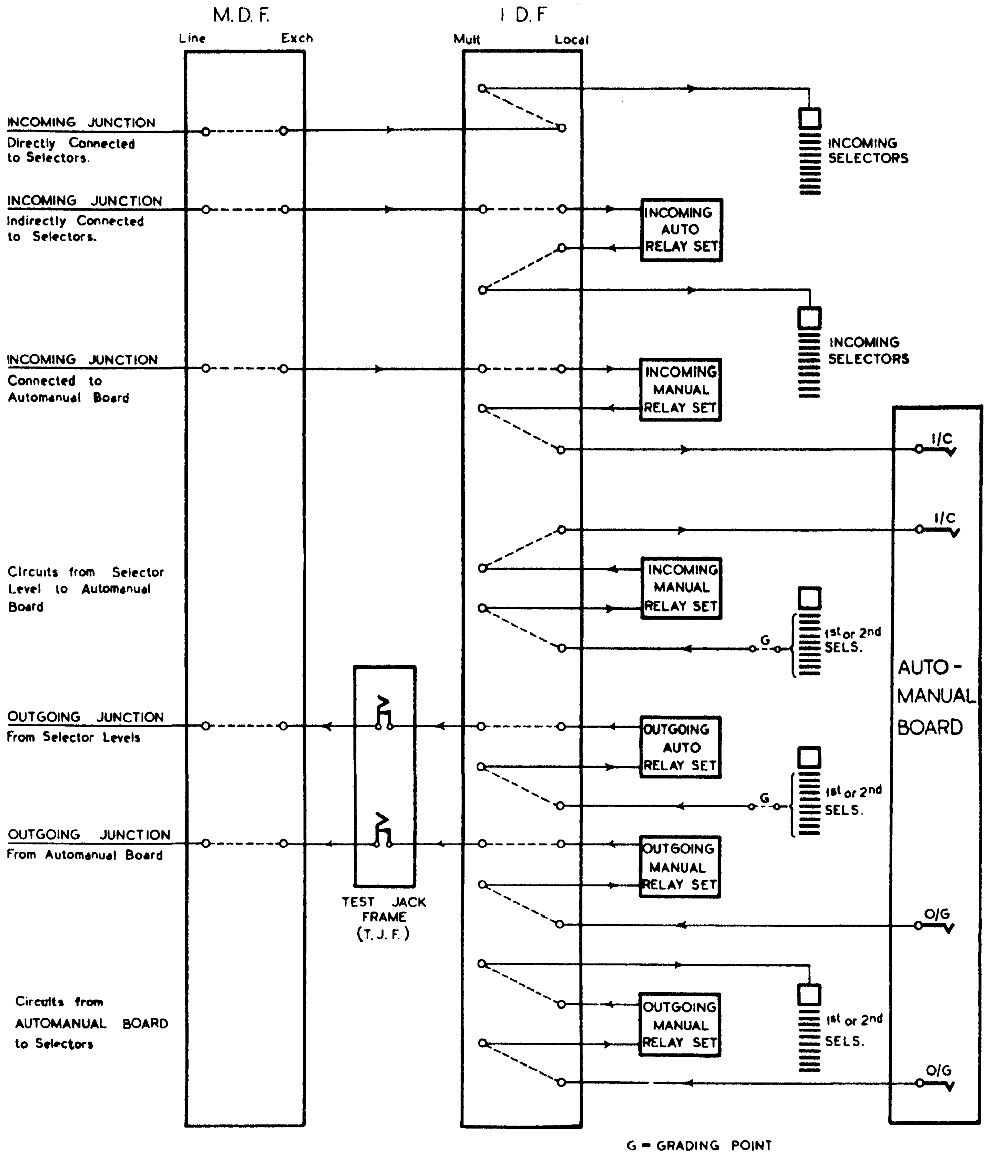


FIG. 176. CABLING AND JUMPERING OF RELAY SETS, MANUAL BOARD CIRCUITS AND JUNCTIONS

side of the I.D.F. and is required only for incoming junctions which are directly connected to selectors. The second (and usually the largest) group terminates on the multiple side of the I.D.F., and provides for all incoming junctions which are not directly connected to selectors, i.e. where there is an incoming relay set or where the circuit is terminated the M.D.F. and the multiple side of the I.D.F. and is routed through the test jack frame (T.J.F.) in order to provide testing facilities on outgoing junction routes.

There is a very large number of relay sets to cater for various conditions. In general, the relay sets are terminated on the I.D.F. in such a way

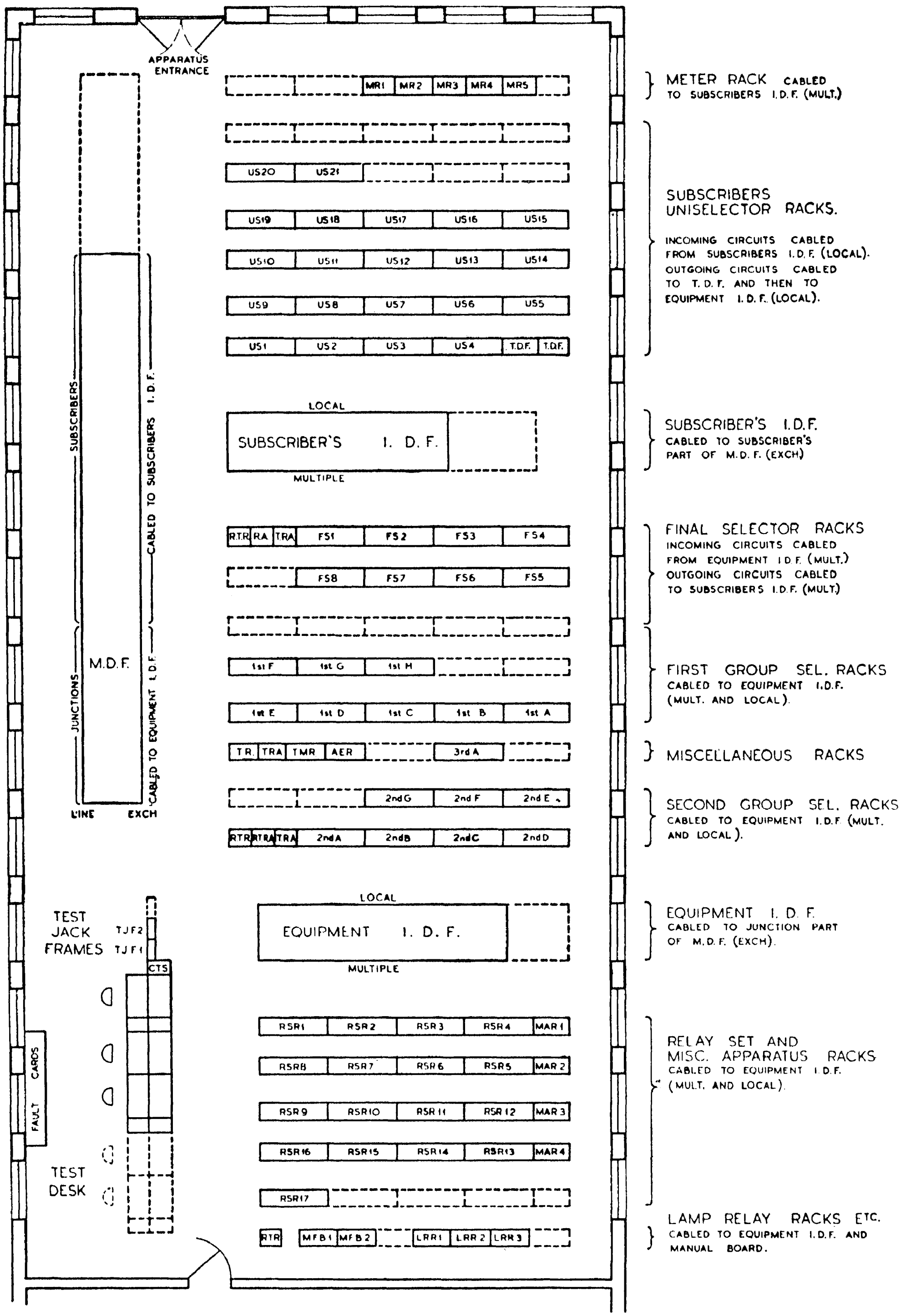


Fig. 177. Typical Lay-out of Automatic Exchange Apparatus Room

that simple across-the-frame jumpers can be used. This is not possible in all cases, and there are some instances where it is necessary to jumper from one connexion strip to another connexion strip on the same side of the frame. It should be noted that both the incoming and outgoing circuits to the manual board jacks are terminated on the local side of the I.D.F.

Lay-out of Apparatus Room. The lay-out of the equipment in an automatic exchange apparatus room can vary considerably. Not only does the shape of the apparatus room differ widely between different exchanges, but the quantity and types of equipment is also very different. There are, therefore, no hard and fast rules for the disposition of the apparatus racks, frames, etc., but there are certain guiding principles which must be followed in preparing the floor plan of a new exchange. In the first place, the position of the M.D.F. is usually predetermined by the position of the cable chamber and the point at which the underground cables are led into the building. The M.D.F. is usually located immediately above the cable chamber and near one of the longer walls of the exchange building. The size of the M.D.F. is usually determined by the number of underground cable pairs which are to be terminated, and it is important that sufficient space should be left for growth to meet the ultimate requirements of external plant. It is usual to locate the line side of the M.D.F. close to the external wall, so that the exchange side faces the apparatus to which it is cabled. If the test desk is to be located in the apparatus room, it should be placed as near as possible to the M.D.F. in order to facilitate testing. It is, at the same time, also desirable that the test desk should be placed (wherever possible) at a part of the room where the noise from the apparatus is a minimum.

The Intermediate Distribution Frame (I.D.F.) is cabled both to the M.D.F. and to the apparatus racks. It has been the practice in a large number of cases to install the I.D.F. parallel to the M.D.F. so that a comparatively simple cabling scheme between the two frames can be employed. The disadvantage of this arrangement is that the two frames together take up a considerable portion of the width of an ordinary apparatus room. The introduction of the group selector rack with grading facilities increases the number of circuits which are to be terminated on the I.D.F., and modern practice favours the division of the I.D.F. into two portions (the subscribers' I.D.F. and the equipment I.D.F.) which can be located at different parts of the apparatus room to give the most satisfactory and most economical cabling arrangement. In Fig. 177 the equipment I.D.F. is located at right angles to the M.D.F. and is placed between the group selector racks and the relay set racks—both of which involve extensive cabling to the I.D.F. The I.D.F. is also so located that it is near the test jack frame and the non-growing end of the M.D.F. where the junction and trunk circuits are terminated.

The subscribers' I.D.F. is cabled to the subscribers' part of the M.D.F. (usually the growing end), the uniselector racks and the final selector racks. In addition there is a small group of cables to the meter rack. It follows that a good position for the subscribers' I.D.F. is between the final selector racks and the uniselector racks, and adjacent to the subscribers' part of the M.D.F. (see Fig. 177).

The lay-out of the apparatus racks themselves must allow for the ultimate requirements of the exchange so far as they can be envisaged at the opening. From a maintenance point of view, there are great advantages in having all racks of one type in a common sequence rather than dotted about at various points of the exchange. It is usually inadvisable to arrange the apparatus racks in suites of more than 5 or 6 racks. If the apparatus room is abnormally wide, then it may be desirable to break down the suites by means of a centre gangway.

The meter racks require only a comparatively small amount of cabling to the subscribers' I.D.F., and from an engineering point of view can be located at any convenient point. In some of the larger exchanges the racks are installed in a separate room so that the noise of the exchange does not interfere with meter reading. Where this is not practicable, it is best to choose a location which is as far as possible away from the noise of the exchange, and where there is an adequate amount of natural lighting. If there is an automanual exchange, the equipment I.D.F. should be so located that it provides a clean and economical cable run for the answering and outgoing multiples of the manual board. The lamp relay racks (*LRR*, Fig. 177) must also be so located that there is a minimum potential drop in the cables to the manual switchboard.

In addition to the main apparatus racks, there is a number of miscellaneous racks, such as routiners, traffic recorder racks, etc. These racks should be so located that their position is economical from a cabling point of view and is convenient for the maintenance staff.

A wide apparatus entrance is normally provided in every automatic exchange apparatus room. The lay-out of the equipment should be such that the growth of the exchange does not block the entry of further apparatus.

EXERCISES IV

1. Describe the construction of the apparatus rack standardized for use in automatic exchanges, and the method of mounting 2-motion selectors.

2. Describe how the various racks, shelves, selectors, etc., of an automatic exchange are designated for reference purposes.

3. Explain how trunking charts facilitate the tracing of a call through an automatic exchange. What information is given on the trunking charts provided on 1st group selector racks?

4. In a certain exchange, the outlets from 1000 subscribers' uniselectors are to be trunked to 100 1st group selectors via an 8-group grading. Describe (with the aid of suitable sketches) the arrangements at the trunk distribution frame and how the uniselector and selector racks are cabled to this frame.

5. Describe a method of grading the outlets from group selectors by means of a commoning scheme on the group selector racks. What are the advantages of this method as compared with a scheme utilizing trunk distribution frames?

6. Draw a schematic cabling diagram for a 4-digit non-director exchange with primary line-finders, showing the connexions and wiring of the main, intermediate, and trunk distribution frames concerned in a call between two subscribers on the same exchange. To what points on the trunk distribution frame can three meters be connected to record the traffic conditions in a grading, and what use is made of the information obtained from each of these meters? (*C. & G. Telephony, Grade III*, 1945.)

7. The initial multiple capacity of a certain automatic exchange must make provision for 1600 subscribers' lines. All the final selectors are to be of the 200-line type and each final selector rack will accommodate 60 such selectors. It is anticipated that, at the ultimate date, the volume of incoming traffic will require 38 switches in each final selector group. Show—

(*a*) The arrangement of the multiple over all the final selector racks.

(*b*) The points where the multiple is terminated on connexion strips.

(*c*) The points at which the outgoing cables to the I.D.F. are terminated.

8. Give a schematic cabling diagram of a 5-digit exchange with subscribers' uniselectors where grading facilities are provided on the group selector racks. Indicate on the diagram the cabling and cross-connexions required to route a call from a 1st group selector level to an automanual board in the same building.

9. When is it advantageous to provide separate "equipment" and "subscribers'" I.D.F.s in an automatic exchange? How should these I.D.F.s be located in relation to the M.D.F.?

10 What considerations determine the lay-out of the racks and frames in the apparatus room of a non-director automatic exchange? Give a sketch showing the floor plan of equipment in the apparatus room at a 4-digit non-director exchange of medium size. (*C. & G. Telephone Exchange Systems II*, 1948.)

CHAPTER V

IMPULSING CIRCUITS

In addition to its primary function of selecting (under the control of the subscriber's dial) any required number, an automatic system must also perform numerous secondary but essential operations which are normally carried out visually and orally by the telephonist of a manual system. Moreover, a subscriber who controls the setting up of his call by the operation of the dial must, from a circuit design point of view, be considered as an unskilled operator and hence the arrangements must cater for the possibility of mis-operation by the subscriber. Furthermore, machine switching equipment, unlike a human operator, cannot exercise initiative to deal with abnormal conditions which, although of rare occurrence, may sometimes happen in practice. Modern automatic circuit design is therefore largely the result of experience gained under working conditions.

Automatic switching circuits are, when considered as a whole, generally very complex, but each individual circuit is built up of a number of comparatively simple and well-established circuit elements. A selector circuit may, for example, contain an *impulsing circuit* which controls the movement of the selector wipers under the direction of the dial impulses, a *hunting circuit* which causes the wipers to search automatically over the outlets on the chosen level and a *switching circuit* by means of which the caller is switched to the selector of the next stage after a free outlet has been found. There are other circuits required for the return of tones, for the guarding of a call during the setting up and the conversational periods, and so on. Before complete circuits can be examined effectively it is necessary that the student should have a thorough knowledge of the common and basic elements. If the various elements can be recognized, it remains only to observe the method of associating the elements in any particular circuit. It is the purpose of this chapter to analyse the problem of controlling the movement of automatic mechanisms from the impulses received from the subscriber. Chapters VI to XI are concerned with other common elements. It is, of course, impossible to consider all the innumerable methods which can be or have been employed, and hence the elements illustrated in the volume are, in general, restricted to those utilized in Post Office standard circuits (both pre-2000 and 2000 type). Circuit elements which are not of general application are considered later in connexion with the circuits to which they are applied.

Repetition of Dial Impulses to Selector Magnet. It is a basic feature of all step-by-step systems that each impulse from the subscriber's dial causes the selecting mechanism to make one step in the process of selection. Usually each break impulse from the dial is made to energize an electromagnet which in turn causes the selector wipers to make one step. Whereas an impulse from the subscriber's dial is an interruption of the current in the line, the corresponding impulse to the selector magnet must be the starting and stopping of a current. Moreover, the current required to energize a selector magnet is comparatively heavy and cannot be controlled directly from the subscriber's loop. It is clear, therefore, that a relay must be inserted in the line circuit to convert the *break impulses* from the dial into *current impulses* of similar duration to energize the selector magnet.

An elementary impulsing circuit is illustrated in Fig. 178. Relay A is the *impulse accepting relay* and is bridged across the speaking pair. The relay often forms part of the transmission bridge and it must therefore possess a comparatively low ohmic resistance coupled with a high impedance to speech currents in order to minimize the transmission loss. Moreover, its two windings must be electrically balanced to equalize the impedance of each line to earth. When the selector is seized by the closure of the subscriber's loop, relay A is energized and during the transmission of an impulse train its contact ($A1$) releases during the break period of each impulse, thereby giving a corresponding pulse of current to the selector driving magnet (DM) for each impulse received.

Preparation, Guarding and Holding. Apart from impulsing requirements, every automatic switching circuit must provide the following basic facilities:

(*a*) The circuit must be *guarded* against intrusion (or *engaged*) immediately it is seized by a calling subscriber.

(*b*) The circuit must be *prepared* in readiness to receive the impulse trains from the calling subscriber and for the subsequent hunting, testing and switching to the required outlet.

(*c*) Provision must be made for the *holding* of the connexion under the control of the calling subscriber during the progress of the call, and for the

release of all the equipment when the calling subscriber replaces his receiver.

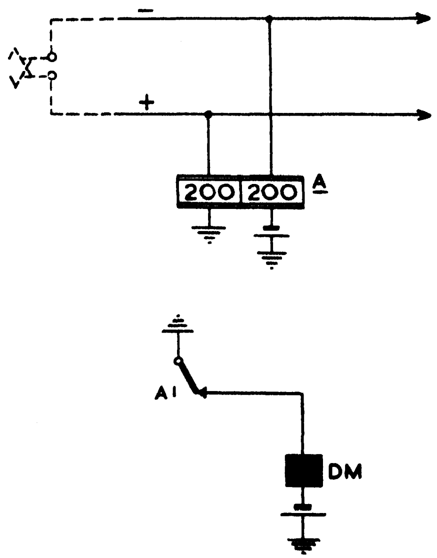


FIG. 178. REPETITION OF DIAL IMPULSES TO SELECTOR MAGNET

(*d*) The initial guarding condition must be maintained without interruption during the setting

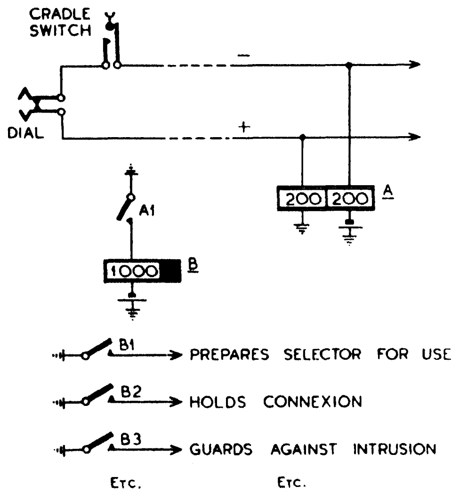


FIG. 179. USE OF SLUGGED RELAY TO MAINTAIN HOLDING CONDITION DURING IMPULSING

up of the connexion, during the conversational period, and (as far as possible) during release.

All these requirements are dependent upon the d.c. loop from the subscriber's instrument which is extended to the selector on seizure of the circuit. A line relay, bridged across the speaking pair, is required to detect the loop and disconnexion signals from the subscriber. This relay can be used to prepare the circuit in readiness for use, to apply the necessary holding and guarding conditions during the progress of the call, and to release the connexion when the d.c. loop is broken by the calling subscriber replacing his handset.

It is undesirable, and indeed unnecessary, to have two line relays—one to provide the holding and guarding conditions, etc., and the other to repeat the impulses to the selector driving magnet. It is the usual practice to utilize the same line relay

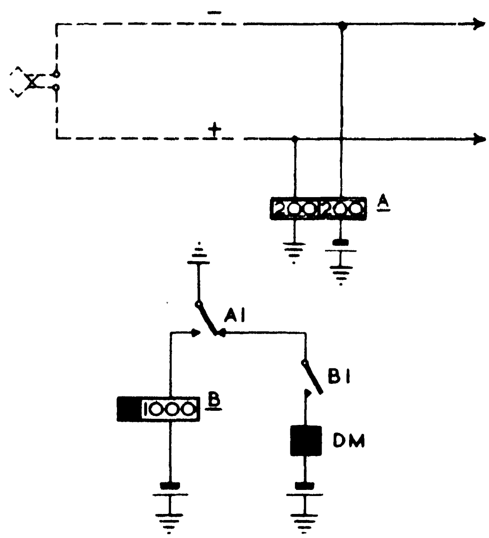


FIG. 180. INTRODUCTION OF *B* RELAY IN IMPULSING CIRCUIT

for both purposes. With this arrangement it is necessary to prevent a false clearing signal being given to the equipment when the line relay releases at each impulse from the calling subscriber's dial. The requirements can be met by providing a relief relay (usually designated *B*) which is dependent upon the line relay, but has a sufficiently long release lag to hold during the short periods when the line relay is released during impulsing.

Fig. 179 shows the basic circuit of a selector hold relay. Relay *A* is the common line relay. When the calling subscriber's loop is extended to the selector, relay *A* operates and at **A1** energizes relay *B*. Some contacts of the *B* relay prepare the selector circuit for use, whilst other contacts apply the necessary holding and guarding conditions. Relay *A* releases in response to each impulse transmitted from the calling subscriber's dial, and at *A*1 disconnects the circuit for a period of some

66 msec as each impulse is received. The slug on the *B* relay is, however, sufficient to hold the relay during the periods when the holding circuit is disconnected at the *A*1 contact.

Impulsing Circuit With *B* Relay. A simple circuit element combining the selector stepping circuit and the holding relay is illustrated in Fig. 180. In this circuit a single changeover contact is used both to control the *B* relay and to repeat the impulses to the selector driving magnet. Relay *A* operates from the subscriber's loop when the circuit is seized and at ***A*1** energizes *B*. ***B*1** in turn prepares the circuit for the selector driving magnet which is subsequently stepped at each release of the *A*1 contact as the impulses are received. It will be noted that the introduction of the *B*1 contact prevents the continuous energization of the selector magnet when the *A*1 contact is at rest.

A further variation of the elementary impulsing circuit is shown in Fig. 181. The changeover (break/make) contact of relay *A* has now been replaced by a contact of the make-before-break type. This arrangement is now standard practice in all modern automatic selector circuits, since it gives the maximum length of pulse both to the *B* relay and to the magnet without the loss due to the transit time of a simple changeover *A* contact.

The operating and, more particularly, the holding conditions of the *B* relay are of importance. In the first place it is clear that the operating lag of the *B* relay must be sufficiently short to prepare the impulsing circuit before the first impulse is received. Normally the subscriber does not commence dialling until he receives dial tone from the 1st selector. Under these conditions the *A* relay is energized for at least 400 msec before the first impulse is received, and there is adequate time for the *B* relay to operate and prepare the impulsing circuit. On subsequent digits, however, the amount of time available is more limited and conditions may occur where substantially the whole of the interdigit pause is absorbed by the hunting time between successive stages of selection. Under these conditions the first impulse may arrive very shortly after the initial operation of the *A* relay, and it is consequently very desirable that the operate lag of the *B* relay should be as short as possible.

It has already been stated that the *B* relay must remain operated during the repetition of impulses to the selector magnet. Fig. 182 shows diagrammatically the flux variations in the *B* relay during a long impulse train. When the *A*1 contact releases for the first impulse, the flux in the *B* relay decays gradually due to the eddy currents in the copper slug which oppose the flux decay in the core. At the termination of the impulse, contact ***A*1** remakes and the current commences to rise in the *B* relay coil. The slug current must now reverse in direction so that there is some delay in the rise of flux. The make period between impulses is comparatively short (nominally $33\frac{1}{3}$ msec) and the time is insufficient for the flux to rise to its previous maximum value. The second break impulse follows and the flux again decays during the $66\frac{2}{3}$ msec (nominal) break period. At the end of the second impulse, the circuit for *B* is again

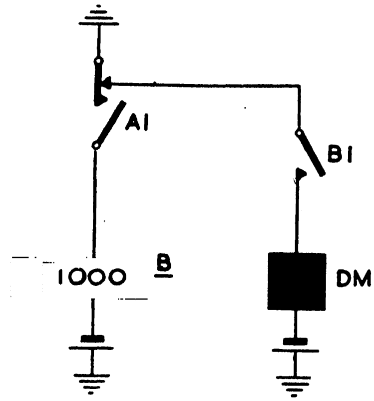


FIG. 181. USE OF MAKE-BEFORE-BREAK IMPULSING CONTACTS

restored and the flux commences to rise but, here again, the make period is insufficiently long to allow the flux to regain the peak value between the first and second impulses.

This process continues throughout the impulse train, the flux of the *B* relay gradually becoming smaller. The rate of decline of flux in the *B* relay decreases somewhat towards the end of the impulse train due to the more rapid rise of flux and the lower rate of decay at the smaller flux values. If the impulse train is sufficiently long, a balance is ultimately reached when the increase of flux during the make period may equal the decay of flux during the longer break period. It is important that during the longest possible impulse train (i.e. 10 impulses) the flux in the *B* relay does not, at any time, fall below the release value. The most dangerous point is at the end of a 10-impulse train, and, if the *B* relay releases, the impulsing circuit to the magnet is disconnected and the holding conditions of the selector are broken down. It is clear that the satisfactory holding of the *B* relay during impulsing is dependent upon:

(*a*) The rate of rise of flux in the relay.
(*b*) The rate of decay of flux.

(c) The ratio of the make to the break period of the impulses received.

With a *B* relay of given design the rate of growth and rate of decay of flux are fixed. The performance is therefore dependent upon the *ratio* of the impulses received. Fig. 182 shows the effect of different impulse ratios upon the performance of a *B* relay which is fully fluxed prior to impulsing (i.e. pre-operated). The full-line curve shows the decline of flux during a long train of standard frequency, but when the frequency is very low the *duration* of the break period (and not the ratio) becomes the controlling factor. At very low frequencies, the duration of the break period may become greater than the static release lag of the *B* relay so that the relay releases during the impulse irrespective of the impulse ratio. With a static release lag of 300 msec and the standard impulse ratio (66 per cent break), this condition occurs when the impulse frequency falls below 2·5 I.P.S.

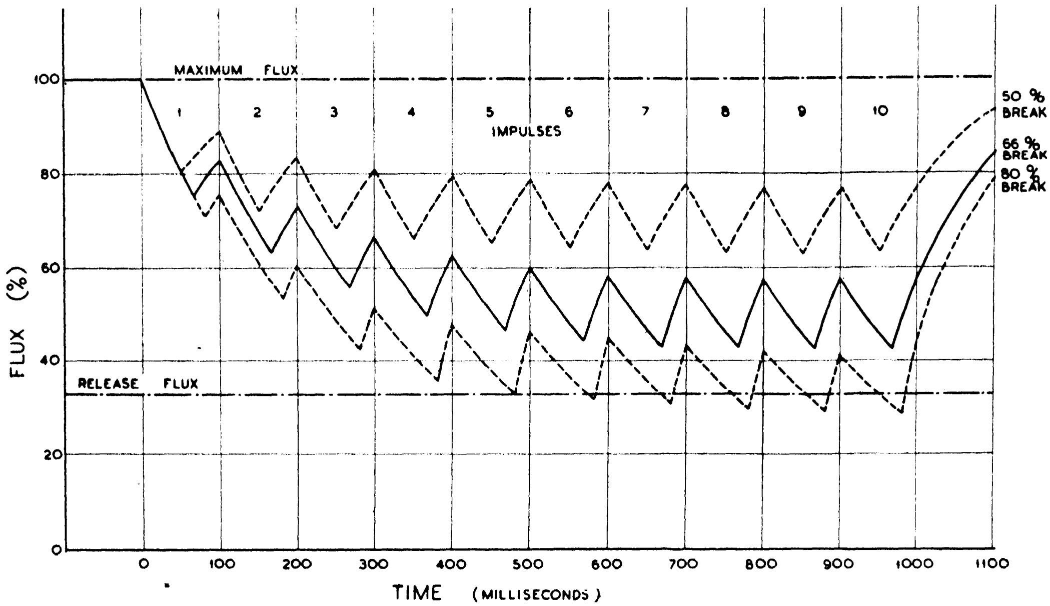


Fig. 182. Holding Conditions of *B* Relay

impulses (i.e. 66 per cent break), whilst the broken lines show the effect of impulse trains having 50 per cent and 80 per cent break ratios. As is to be expected, the smaller the break ratio the more reliable is the *B* relay. On the other hand, if the break ratio increases beyond a certain critical value, there is a danger that the flux may fall (during a long impulse train) below the release value for the relay. Whereas the actual *length* of the make and break periods determines the performance of the selector magnet, the *ratio* of the impulses is (over a given frequency range) the governing factor for satisfactory holding of the *B* relay. The performance of the *B* relay does, of course, depend to a large extent upon the spring load, but it is possible to design a slugged *B* relay which will retain satisfactorily with impulse ratios of up to 75 or even 80 per cent break.

At all normal dial speeds the performance of the *B* relay is substantially independent of the impulse The limitation is therefore of little practical significance.

Before leaving Fig. 182 it is desirable to note that, if a call is released during the reception of an impulse train, the release lag of the *B* relay may be considerably less than the static lag when the relay is released after full saturation. If at the time of disconnexion the flux is just above the release flux, then there will be no appreciable release lag. On the other hand, if the relay is released at the commencement of an impulse train, the release lag may be not very much less than the static lag. This is an important factor which must be considered in the design of holding and guarding circuits.

Usually a $1\frac{1}{2}$ in. slug is necessary to meet impulsing conditions and this absorbs a large part of the available winding space on a telephone relay. In practice, the *B* relay has numerous functions, and a large spring pile is often required.

Very careful design is therefore necessary to produce the required tractive force with the small amount of winding space available and at the same time to meet the impulsing conditions. In some cases it is necessary to specify light spring pressures and a very low residual value, whilst in other circuits a relief relay has to be introduced.

Use of Short-circuited *B* Relay. Some improvement of the impulsing circuit can be made by fitting a metal rectifier across the *B* relay in addition to a slug. By this means, the decay of flux is slowed down on release without affecting the rate of flux rise on operation. (See Vol. I.) This arrangement has been used on a number of pre-2000 type circuits, but with the advent of the 2000 type switch a new principle utilizing a short-circuited *B* relay was introduced. The *B* relay

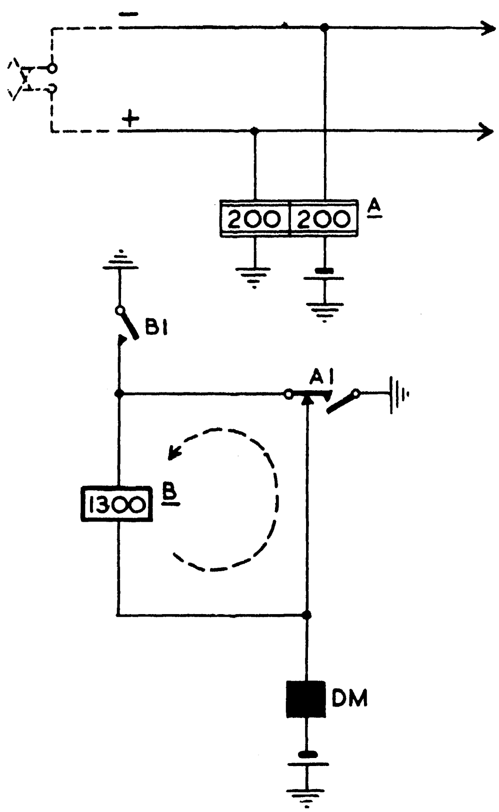


FIG. 183. IMPULSING CIRCUIT WITH *B* RELAY SHORT-CIRCUITED DURING IMPULSE PERIOD

(Fig. 183) has a fully wound spool but no slug. When relay *A* operates to the subscriber's loop, *A*1 energizes the *B* relay in series with the selector driving magnet (the current is, of course, insufficient to operate the magnet). At each break impulse *A*1 falls back and extends the earth at ***B*1** to step the driving magnet. At the same time, *A*1 short-circuits the *B* relay but the latter holds due to the eddy currents (shown dotted) in the closed circuit. The advantages of this new arrangement are:

(*a*) The rise of flux in the *B* relay on operation and between impulses is very rapid due to the absence of a slug.

(*b*) All the winding space can be used for the energizing winding, thus permitting higher spring pressures or a greater number of contact springs.

(*c*) All the winding space functions for slugging purposes.

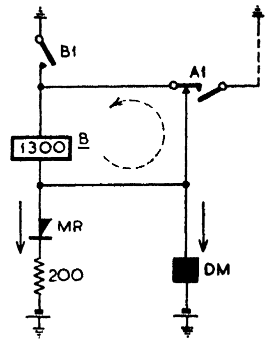


FIG. 184. ALTERNATIVE ARRANGEMENT WITH SEPARATE BATTERY FEED TO *B* RELAY

(*d*) The back e.m.f. of the magnet assists the growth of flux in the *B* relay at the end of each impulse.

(*e*) The passage of the *B* relay current through the magnet between impulses reduces the operate time of the magnet but also tends to increase the release lag of the magnet.

The introduction of the short-circuited *B* relay has materially improved the permissible impulsing limits. For example, with a slugged *B* relay it was possible to allow (at 12 I.P.S.) an impulse ratio up to about 80 per cent break. With the short-circuited *B* relay, the circuit will function satisfactorily with an impulse ratio of up to about 90 per cent break.

It will be noted that in Fig. 183 the battery supply to the *B* relay is fed via the selector driving magnet (*DM*). In some cases this arrangement saves the provision of a protective resistor in the battery supply circuit. (The protective resistor is, of course, necessary to avoid blowing the fuse when the *B* relay is short-circuited on the release of *A*1.) In some circuits it is inconvenient to derive the *B* relay battery from the driving magnet and in these circumstances one side of the *B* relay is connected to a separate battery via a protective resistor of 200 Ω (Fig. 184). If such a separate battery feed to the relay is provided, a metal rectifier must be connected in series with the protective resistance to avoid the slugging effect on the magnet of the shunt path. The rectifier (*MR*) is connected so that the normal current through the *B* relay passes through the rectifier in the conducting direction, whilst any circulating currents which tend to prolong the release of the magnet are prevented by the high

impedance of the rectifier in the non-conducting direction.

There is an interesting point of difference in the characteristics of slugged and short-circuited *B*

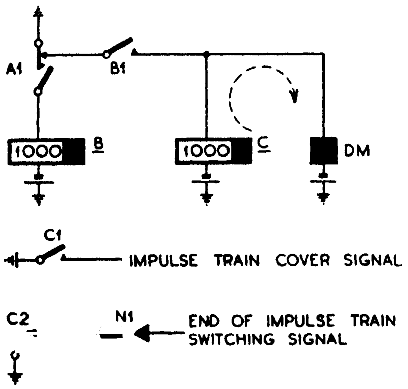


FIG. 185. METHOD OF OBTAINING SIGNALS TO MARK END OF IMPULSE TRAIN

relays. In order to give a satisfactory impulsing performance, a slugged *B* relay must have a static lag of not less than about 250 msec. The short-circuited type of relay will give a better impulsing performance with a static lag as low as 150 msec.

Impulse Train Switching Signals. Most circuits require a signal to indicate the end of the impulse train. For example, in a group selector circuit it is necessary to provide a signal when the impulse train is completely received in order to arrange for the wipers to cut into the selected level and to carry out a search for a free trunk on this level. Similarly, in a final selector circuit it is necessary to provide a signal at the end of the vertical impulse train to rearrange the connexions so that the second impulse train is directed to the rotary magnet. In other circumstances it is necessary to make temporary rearrangements of the circuit during the reception of an impulse train (e.g. in an impulse repetition circuit). This requires a continuous signal from the commencement of the impulse train until the end of the impulse train.

These impulse train switching signals require the use of a third relay (usually designated *C*) in the impulsing circuit. A simple arrangement is shown in Fig. 185. The operation of contact **A1** on seizure of the circuit energizes relay *B*, and ***B*1** prepares the circuit for the *C* relay and driving magnet. On receipt of the first impulse, the release of *A*1 energizes both the driving magnet (*DM*) and the *C* relay in parallel. The driving magnet operates and releases to each impulse received, but the *C* relay is provided with a copper slug so that it holds during the short intervals between impulses. The *C* relay therefore operates shortly after the commencement of the first break impulse, and releases some 100 msec or so after the last impulse has been received. Any contact of the *C* relay can therefore be used to provide a "cover" signal during the impulse train. In order to obtain an end of impulse train switching signal, however, it is necessary to utilize the *C* relay contacts in conjunction with some other contacts which do not close until the *C* relay is operated at the commencement of the impulse train. In Fig. 185, selector off-normal make contacts (*N*1) have been utilized. The *N*1 springs prevent the application of the switching signal before the **C2** contact operates at the commencement of the impulse train, but at the end of the train the restoration of *C*2 gives the required switching signal through contacts **N1**, which are now operated.

The parallel arrangement of the *C* relay and driving magnet (Fig. 185) suffers from the defect

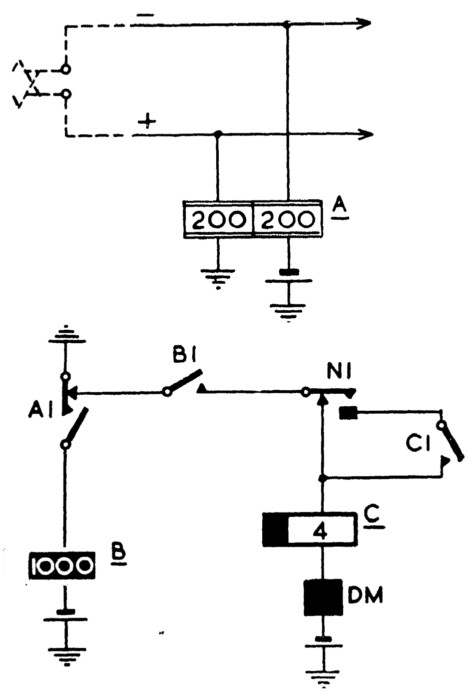


FIG. 186. EARLY IMPULSING CIRCUIT WITH *C* RELAY

that the *C* relay coil acts as a shunt on the driving magnet during release. This tends to prolong the flux in the driving magnet when the **A1** contacts re-operate at the end of each impulse. It is for this reason that, wherever possible, the *C* relay is

placed in series with the driving magnet rather than in parallel.

Impulsing Circuit with *C* Relay. Fig. 186 shows an early arrangement of an impulsing circuit with a *C* relay. Contact **A1** operates relay *B* as previously described and **B1** prepares the circuit to the driving magnet via the make-before-break off-normal contacts of the selector (*N*1) and the 4 Ω coil of the *C* relay. When *A*1 releases on receipt of the first impulse, relay *C* and the driving magnet (*DM*) operate in series. As the selector takes its applied to the *B* relay. The latter is, of course, energized for 33⅓ msec and de-energized for 66⅔ msec as compared with the reverse conditions for the *C* relay. Further examination does, however, show that the operating conditions of the two relays cannot be compared. Whereas the *B* relay is energized for an appreciable period *before* the first break impulse (and hence is fully fluxed at the commencement of the impulse train), the current in the *C* relay commences only at the start of the first impulse, and there is insufficient time for the flux to rise to its maximum value before the circuit is disconnected some 66 msec later.

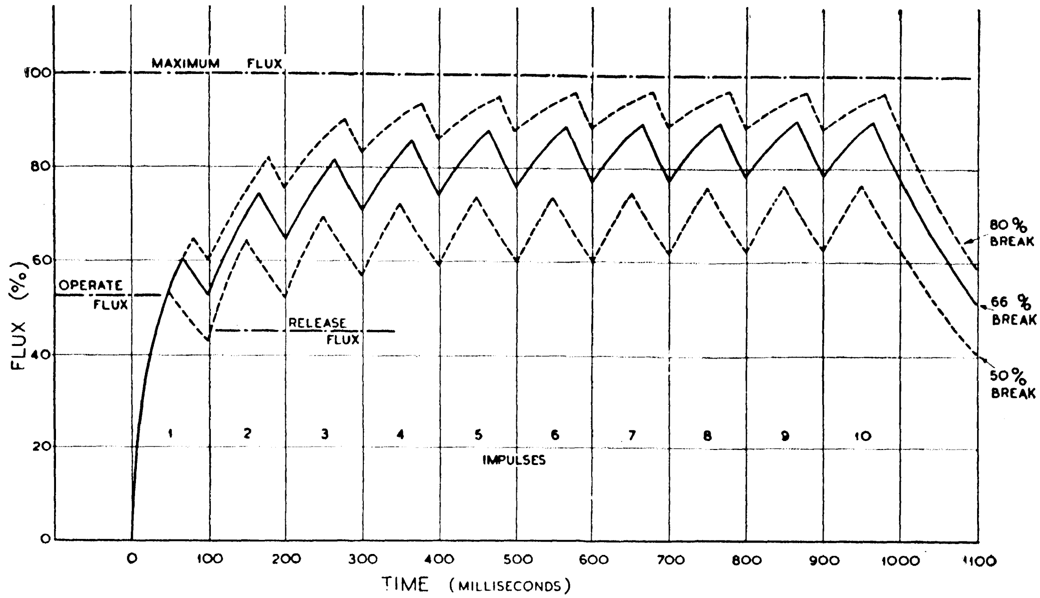


FIG. 187. FLUX IN *C* RELAY DURING LONG IMPULSE TRAIN

first step, contacts **N1** operate but an alternative circuit for the next impulse is provided via **C1**. Subsequent impulses are passed to the driving magnet via **B1**, **N1**, **C1** and the *C* relay. The *C* relay is fitted with a heel-end slug and is designed to hold during the periods when **A1** is operated, but at the end of the impulse train the prolonged operation of **A1** during the interdigit pause enables *C* to release. The release of *C* disconnects the impulsing circuit at *C*1, thereby preventing any further pulses of current to the driving magnet. Other contacts (not shown in Fig. 186) of relay *C* carry out the necessary switching operations as required by the particular circuit.

During impulsing, the *C* relay is energized during the *break* period of an impulse (nominally 66⅔ msec) and must hold by virtue of its slug during the make period between impulses (nominally 33⅓ msec). At first sight it appears that the operating conditions of the *C* relay are less severe than those

The conditions are illustrated diagrammatically in Fig. 187. At the commencement of the first break impulse the flux in the *C* relay rises at a rate which is determined partly by the time constant of the *C* relay and magnet in series and partly by the eddy current effects of the *C* relay slug. The *C* relay and magnet circuit is highly inductive, and hence there is an appreciable delay before the current rises to substantially its maximum value. In addition to this, the growth of flux in the *C* relay is delayed by the effects of eddy currents in the relay slug. It is therefore fundamentally difficult to design a *C* relay in which the flux rises to a high value before the circuit is disconnected at the end of the first impulse. At the end of the impulse period, the flux decays gradually as in any other slugged relay, but the comparatively low maximum value of flux during the first impulse

may allow the flux to fall below the release value of the relay during the ensuing 33 msec make period of the *A* relay contact. If the *C* relay holds during the 33 msec period between the first two impulses, subsequent pulses of current through the relay coil gradually raise the maximum flux in the relay until at the end of the last

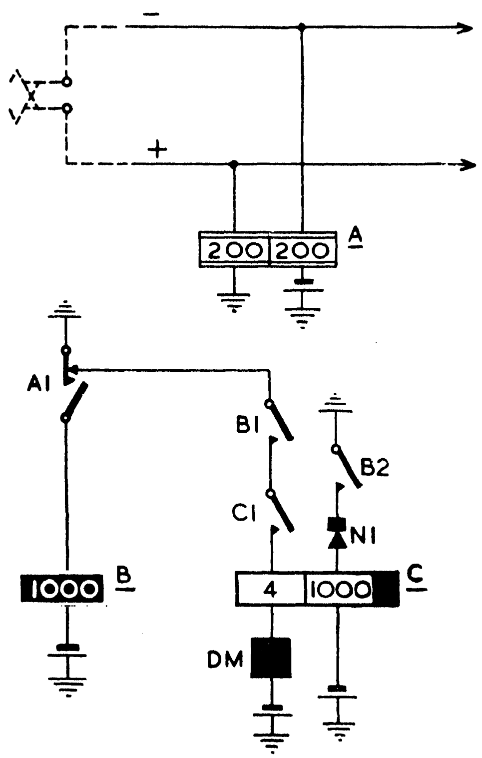


Fig. 188. Impulsing Circuit with Pre-operated *C* Relay

impulse in a long train the relay is almost fully fluxed. It is clear, therefore, that the most dangerous period for the premature release of the *C* relay occurs between the first and second impulses.

With a *C* relay of given design, the available margin of safety depends upon the *ratio* of the impulses. If the break ratio is high, then the *C* relay is energized for a long period during the first impulse and hence can attain a higher maximum flux. Moreover, for a given impulse frequency, a high break ratio gives a shorter period between successive impulses, thereby reducing the time during which the *C* relay flux is falling, and a corresponding higher minimum value of flux. On the other hand, a low break ratio gives less time for the flux to rise in the *C* relay and more time for the flux to fall towards the release value. A high break ratio gives the maximum margin of safety on the *C* relay and, conversely, a low break ratio tends to cause the relay to release prematurely. In Fig. 187 the flux variations in a *C* relay are shown for impulse ratios of 50 per cent, 66 per cent and 80 per cent. It will be noted that, whereas the relay would, under the conditions shown, fail with an impulse train of 50 per cent break, a similar train of impulses where the break ratio is 66 per cent would be safe, whilst the margin of safety is still further increased when the break ratio is increased to 80 per cent.

Pre-operated *C* Relay. A much improved circuit is given in Fig. 188. The *C* relay has now two windings, a low resistance winding in series with the magnet and a high resistance *pre-operating winding* in a local circuit. When the circuit is seized by the calling subscriber, relays *A* and *B* operate and contact ***B2*** energizes the *C* relay on its 1000 Ω coil. The relay is therefore fully saturated before impulsing commences. The driving magnet is stepped as before, and at the first step the pre-operate circuit of *C* is disconnected at the selector off-normal springs ***N1***. Relay *C* is now held during the impulse train by the pulses of current in its 4 Ω coil in conjunction with the relay slug. At the end of impulsing, *C* releases and in so doing breaks the magnet circuit at *C*1 in addition to its other switching functions.

By pre-operating the *C* relay the danger of premature release between the first two impulses of a train is obviated, and the operating conditions of the *C* relay are now substantially similar to those of the *B* relay except that the pulse ratio is 66 per cent of the total impulse time in the *C* relay circuit, whereas the *B* relay is energized for only 33 per cent of each impulse period. The margin of safety of the pre-operated *C* relay circuit still depends upon the break ratio of the dial impulses. If, for example, the impulses from the controlling dial have a low break ratio, it is just possible that the decay of flux during the period between impulses may be greater than the rise of flux during the following impulse. If these conditions obtain, then there is a danger of the *C* relay releasing towards the end of a long impulse train. Apart from the benefits obtained from pre-operation of the *C* relay, the introduction of a second coil for this purpose takes up winding space which could otherwise be utilized for the low resistance coil or the slug. The pre-operated relay is therefore somewhat less efficient than the simple one-coil relay. Nevertheless, a pre-operated *C* relay can be designed to carry a reasonable spring load and to work satisfactorily over a wide range of impulse ratios. A typical relay will perform satisfactorily with impulse ratios as

low as 30 per cent break, which enables a very considerable amount of impulse distortion to occur before failure results.

It should be noted that the pre-operated C relay principle can be employed only in circumstances where facilities are available to disconnect the pre-operate circuit immediately after the first impulse. Such facilities are readily available on 2-motion type selectors in the form of off-normal springs, but in other circumstances the provision of a switching condition after the first impulse may considerably complicate the circuit arrangements. It is, of course, possible to arrange for a separate relay to be operated by B and to release after the first impulse, but this solution adds to the cost and complexity of the circuit.

Generally speaking, when off-normal springs are not available, an ordinary (non pre-operated) C relay is retained. In these circumstances some improvement in performance can be attained by replacing the C relay slug with a low resistance winding which is short-circuited by a contact of the C relay. By this arrangement the effect of eddy currents during the initial operation of the C relay is reduced to a minimum, thereby producing a more rapid rise of flux during the first impulse. Subsequent to the operation of the C relay, the short-circuited winding behaves substantially as a slug to give the requisite slow decay of flux between periods of energization.

Impulsing Circuit with Short-circuited *B* and *C* Relays. Fig. 189 is a development of Fig. 183 to include the switching feature at the end of the impulse train. Both the B and C relays are without slugs, and the required release lags are obtained by arranging for the relays to be short-circuited between current pulses. On seizure of the circuit, **A1** operates relay B to the DM battery via the 500 Ω resistor, **B2** applies an earth in readiness for the completion of the magnet circuit and **B1** pre-operates relay C on its 700 Ω winding. **C1** now finally prepares the magnet circuit in readiness for the release of $A1$.

At the first impulse, $A1$ releases and completes the magnet circuit from the earth at **B2** via **C1** and the 5 Ω coil of C. At the same time B is short-circuited by the $A1$ contact. As the switch steps from its normal position, contacts **N1** short-circuit the 700 Ω winding of C, thereby making the relay slow-to-release. (The 1200 Ω resistance is included to avoid a short circuit on the battery supply when the **N1** contacts operate.) The C relay is also slightly slugged by the 500 Ω shunt across its 5 Ω winding.

The C relay holds during the impulse train due to the pulse of current in its 5 Ω winding during each break period, but, as before, it releases after the last impulse to isolate the driving magnet at $C1$. The release of other C contacts (not shown) prepares the selector for the next operation. The B relay is held during each make period by the earth at **B2** and remains operated during each break period of an impulse due to the slugging

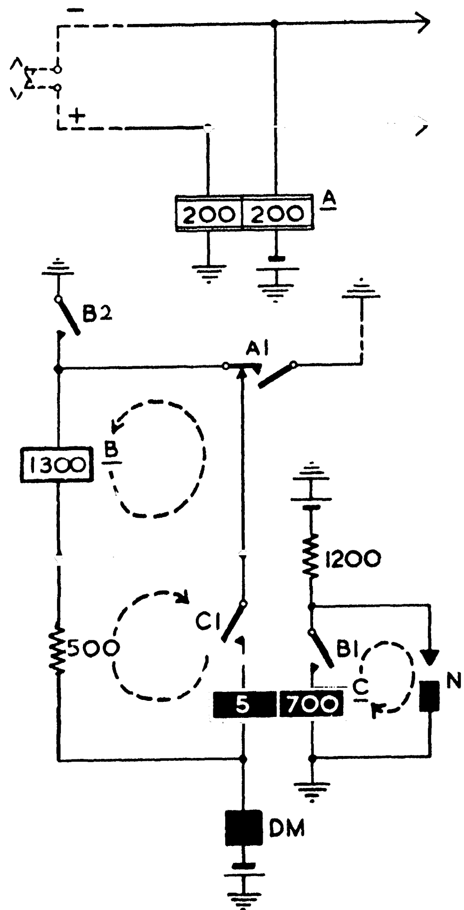


FIG. 189. IMPULSING CIRCUIT WITH SHORT-CIRCUITED B AND C RELAYS

action of its short-circuited winding. This circuit element is standard in all 2000 type selectors.

It is interesting to examine at this stage the effect of "bunching" at the $A1$ contacts. As will be seen later, circumstances may arise where the rise of flux in the A relay is comparatively slow. Under adverse conditions, this slow rise of flux may produce a material time interval between the closure of the "make" part of the $A1$ contact and the opening of the "break" portion of the contact

unit. With the pre-2000 impulsing circuit (Fig. 188) a long bunching time may allow the *B* and *C* relays to operate before the magnet circuit is

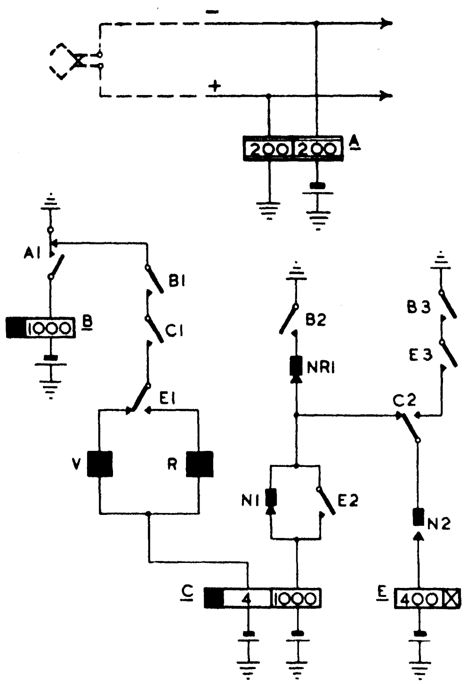


Fig. 190. Complete Impulsing Circuit to Give Vertical and Rotary Stepping Under Control of Dial
(Pre-2000 type selectors)

disconnected at the break contacts of the *A*1 unit —thereby giving a false impulse to the magnet. Impulsing circuits of the 2000 type (Fig. 189) are immune from this trouble due to the fact that the *B* relay cannot operate before the magnet circuit is disconnected at the **A1** contact.

Vertical and Rotary Stepping under Control of Dial. Fig. 190 shows a further development of the impulsing circuit to give both vertical and rotary stepping under the control of two consecutive impulse trains. This complete element is used in such circuits as final selectors, etc., of the pre-2000 type. In order to give vertical stepping during the first impulse train and rotary stepping on the second train, an additional relay *E* must be introduced to change over the circuit from the vertical to the rotary magnet during the pause between digits.

A pre-operate circuit for relay *C* is provided from the earth at ***B*2** via *NR*1 and *N*1. This circuit is broken by **N1** at the first vertical step, and the *C* relay holds during the first impulse train by the current pulses in its 4 Ω coil. At the end of vertical stepping, *C* releases and at *C*2 provides a circuit for relay *E* via ***B*2**, *NR*1, *C*2 and ***N*2**. ***E*1** changes over the impulsing circuit from the vertical to the rotary magnet whilst ***E*2** re-establishes the pre-operate circuit of *C*. ***C*2** in re-operating provides a hold circuit for *E* (via ***E*3** and ***B*3**) under the control of the *C* relay. The *E* relay is provided with an armature-end slug to ensure that it is fully fluxed before ***E*2** re-operates *C*. This is necessary to provide an adequate lag to prevent the *E* relay releasing during the transit time of the *C*2 contacts. The second impulse train steps the rotary magnet, the pre-operate circuit of *C* being broken at ***NR*1** on the first rotary step. *C* releases at the end of the train and at *C*2 releases *E*.

Fig. 191 shows the equivalent circuit element as used on 2000 type circuits. It is substantially similar to the earlier circuit (Fig. 190) except for the use of short-circuited type *B* and *C* relays.

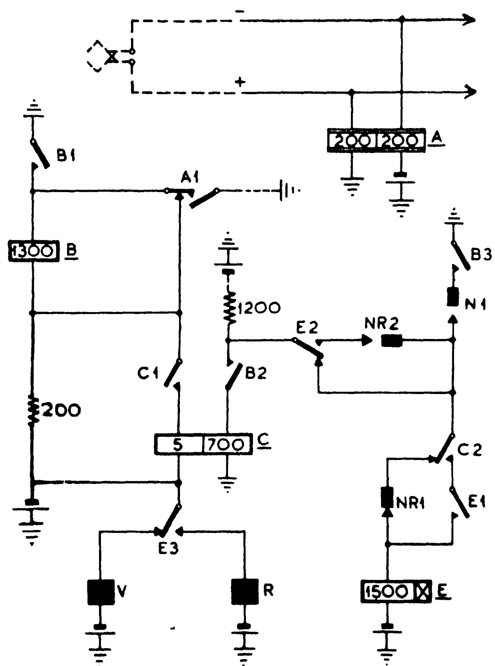


Fig. 191. Similar Impulsing Circuit on 2000 Type Selectors

Relay *C* releases after its period of lag at the end of the vertical impulse train and at *C*2 allows the *E* relay to operate via *NR*1 from the earth at ***B*3**. ***E*2** removes the short circuit from the 700 Ω winding of *C* which was applied by **N1** at the first vertical step. *C*, in re-operating, prepares, at **C1**,

the circuit for the next impulse train, and holds the E relay via **$E1$**, **$C2$** and **$N1$** independent of the $NR1$ springs. **$E3$** changes over the impulsing circuit from the vertical to the rotary magnet.

On the first step of the rotary movement, the rotary off-normal springs **$NR1$** and **$NR2$** are operated, the former leaving the release of E under the control of **$C2$** and the latter re-applying the short circuit to the pre-operating winding of C. At the end of the rotary train, C releases and at $C2$ releases E.

Target Diagrams. It has been seen that the performance of an impulsing circuit is dependent not only upon the impulse frequency and ratio, but also upon the design and adjustment of the B relay, the C relay and the stepping magnet. The effects of a change of impulse frequency cannot be considered without also considering the impulse ratio. Similarly, a change of frequency or ratio may be beneficial to, say, the performance of the B relay but this same change may materially reduce the margin of safety of the C relay and magnet. This interdependence makes it difficult to measure and state in a concise form the breakdown limits of any particular impulsing circuit. It is still more difficult to visualize the margin of safety when impulses between specified limits of frequency and ratio are applied to the circuit.

Fig. 192 shows a form of target diagram sometimes used by circuit designers to facilitate the analysis of impulsing performance. The chart is ruled vertically to show the make period (in milliseconds) of an impulse, whilst the horizontal rulings show the corresponding break period of the impulse. By this means, any impulse can be plotted as a specific point on the chart. For example, an impulse from a dial of 10 I.P.S. with $66\frac{2}{3}$ per cent break is composed (nominally) of a $33\frac{1}{3}$ msec make period plus a $66\frac{2}{3}$ msec break period. Such an impulse can be shown as a single point at the intersection of the $66\frac{2}{3}$ msec break ordinate and the $33\frac{1}{3}$ msec make abscissa of the chart. It should be mentioned at this point that the individual impulses in, say, a train of ten from a dial may differ quite appreciably from the mean values of break and make period. Such differences are largely due to irregularities in the speed of rotation of the dial and to variations in the teeth of the impulsing wheel. The target diagram is useful in this connexion by enabling each impulse of a train to be plotted, and the shape of the group of impulse points may reveal troubles due to faulty design or construction.

It will be noted that the abscissa and ordinate of the target diagram are arranged as logarithmic scales. The advantage of the logarithmic division is that a certain distance between any two points representing two impulses always represents the same *proportionate* change—no matter on what part of the chart the points occur. For convenience of reference the target diagram is also ruled with lines connecting together all points of equal frequency and with a further set of lines to show the impulse ratio. Due to the use of logarithmic scales for the make and break periods, the impulse frequency lines appear as curves whilst the ratio lines are straight and parallel diagonals.

It is now possible to plot on this basic target diagram the impulses received and the failure points of the impulsing circuit. The small parallelogram at the centre of the diagram shows the area into which all impulses from a dial within the specified adjustment limits should fall. The slightly larger figure formed by the broken line indicates the somewhat wider limits assumed for the purpose of circuit design. One of the limits of an impulsing circuit occurs when the break period of a received impulse is insufficient to operate the stepping magnet. This limit can be shown as a horizontal line (at about 30 msec for a 2000 type selector) across the target diagram. The magnet may also fail to release if the make period between impulses is reduced below a certain critical value. This can also be shown on the target diagram as a vertical line in the appropriate position. At all normal dial speeds the failure of the B relay depends upon the ratio of the impulses received and hence can be shown as a diagonal line on the diagram. The C relay is similarly dependent upon the ratio of the impulses, and its failure points can be plotted as another diagonal line at a low value of break ratio. Finally, an impulsing circuit may fail at low impulse frequencies when the length of the break period is greater than the static lag of the B relay or when the make period is greater than the static lag of the C relay. These two factors can be shown as horizontal and vertical lines respectively on the target diagram.

The limits of the complete impulsing circuit can be illustrated by a 6-sided figure on the target diagram as shown in Fig. 192. If the plot of any impulse falls outside this figure, the circuit will fail due to one cause or another. For example, an impulse with make and break periods each of 25 msec will produce a magnet failure, whilst an impulse of the same make period but with a break period of, say, 250 msec, will allow the B relay to release. The distance between the small parallelogram showing the dial limits and the larger diagram of the impulsing circuit gives a measure of the margin of safety of the circuit. In Fig. 192 the maximum permissible range of impulse ratio (i.e.

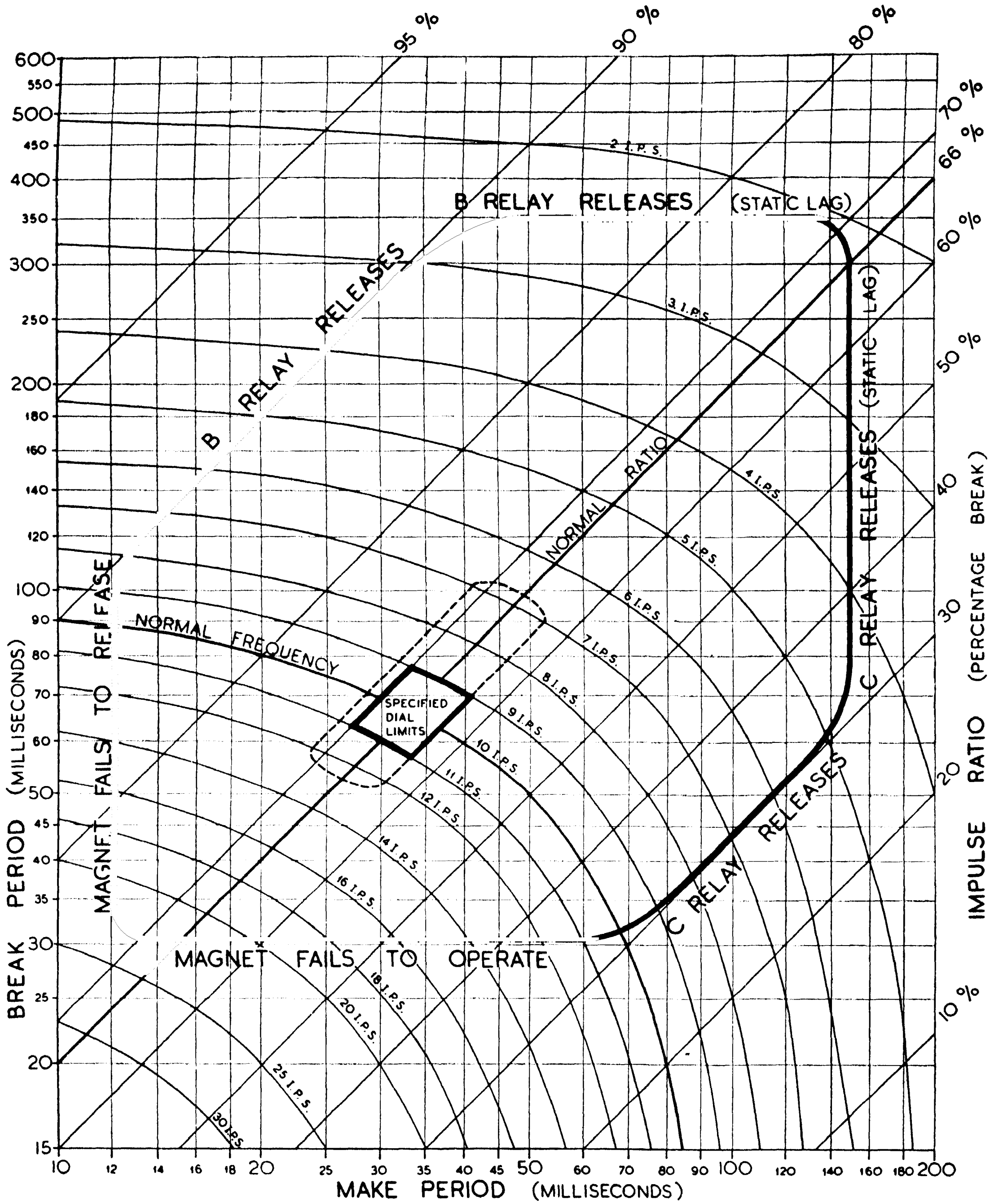


FIG. 192. TYPICAL TARGET DIAGRAM DESIGNED TO SHOW LIMITING FACTORS OF IMPULSING CIRCUIT

from about 30 per cent to 90 per cent) is obtained when the impulse frequency is between 5 and 10 I.P.S. As the impulse frequency is increased or decreased beyond these limits, the allowable ratio rapidly narrows due to the convergence of the horizontal and vertical lines of the target diagram.

Target diagrams of the type illustrated are particularly useful in studying the effects of impulse distortion. If the line characteristics and other factors produce an impulse ratio at the impulsing relay contacts which differs from the original ratio at the dial, then the centre parallelogram is moved in one direction or the other along the frequency line. A distortion which reduces the break ratio, for example, will move the parallelogram to the right and downwards—thereby reducing the operating margin of the magnet or, at lower frequencies, the holding margin of the *C* relay.

Alternative Impulsing Circuits. It has been explained that the successful operation of the *B* and *C* relays is determined by the ratio of the impulses received. Whilst this is true for impulsing circuits of the accepted design, there is no fundamental reason why the *B* and *C* relays should be dependent upon the impulse ratio. It will be recalled that the *B* relay is required to hold during impulsing but to release within a reasonable period after the calling subscriber has replaced his receiver. Similarly, the *C* relay must hold during the impulse train but should release as soon as possible after the last impulse of the train has been received. It is clear, therefore, that if a circuit could be devised whereby the *C* relay is held independently of the incoming impulses until after the termination of the last impulse, the basic requirement is met. Such a circuit would be completely independent of the ratio of the impulses. Similarly, if, after the release of the *A* relay, the *B* relay is held for a fixed time which is greater than the maximum possible length of an impulse period (make + break), then this relay also can be made entirely independent of the impulse ratio.

For example, if it is assumed that the lowest permissible impulse frequency is 7 I.P.S. (any desired lower limit can be fixed), then the length of one impulse period = 1000/7 = 143 msec. If, now, the circuit is arranged so that the *C* relay is held for, say, 150 msec after the commencement of the last break impulse, the circuit is completely unaffected by the ratio of the last or any of the preceding impulses. Also if the same delay time is applied to the *B* relay, this relay cannot possibly release during impulsing unless the impulse frequency falls below the design figure of 7 I.P.S. Various schemes based on the above principle have been suggested from time to time. In one recent invention* use is made of the charging time of a capacitor to give the required fixed time period.

Impulse Distortion. So far it has been assumed that the impulses from a subscriber's dial are repeated faithfully to the relays and magnets of the impulsing circuit. Such conditions would obtain if a circuit could be designed in which the *A*1 contacts release at precisely the same moment as the dial impulse springs open, and re-operate at the same instant as the re-closure of the dial springs. These conditions would require an impulsing relay (*A*) with zero operate and release lags and a circuit in which the current in the *A* relay is precisely the same as the current through the dial impulsing contacts. Such conditions are, of course, unobtainable in practice due to the mechanical and electrical characteristics of the impulsing relay itself and also on account of the electrical constants of the line connecting the subscriber's instrument to the exchange.

The best that can be done is to so design the impulsing relay that *under average line conditions* the operate lag will be equal to the release lag of the relay. If this can be achieved, then the impulses transmitted to the selector circuit will have the same ratio as the original impulses from the dial. It is true that the impulses passed on to the selector circuit will lag behind the dial impulses by a period depending upon the operate (or release) lag of the *A* relay, but this is of no consequence so long as the original impulse ratio is retained. If the ideal conditions for distortionless repetition cannot be obtained, then there will be some degree of *impulse distortion* depending upon the difference between the operate and release lags of the *A* relay. Such distortion is illustrated in Fig. 193. It is assumed that the impulse frequency is 10 I.P.S. and that the impulse ratio at the dial springs is $66\frac{2}{3}$ per cent break. If the release lag of the *A* relay is 20 msec, the first break impulse will not commence until 20 msec after the break of the dial springs. Similarly, if the operate lag of the *A* relay is, say, 10 msec, the **A1** contacts will re-operate 10 msec after the re-closure of the dial impulse springs. The net result of the unequal operate and release lags is that the original break period of $66\frac{2}{3}$ msec is distorted at the *A*1 contact to a break period of $56\frac{2}{3}$ msec, and, similarly, the make period is distorted from $33\frac{1}{3}$ msec to $43\frac{1}{3}$ msec. This gives an effective break ratio at the *A*1 contact of $56\frac{2}{3}$ per cent as compared with the original ratio of $66\frac{2}{3}$ per cent. In the same way, if the operate lag of the *A* relay is greater than its release lag,

* British Patent 549047 (Automatic Telephone and Electric Co., Ltd.).

then the break period and the percentage break ratio are increased. There are thus two forms of distortion which must be considered:

(*a*) Distortion which reduces the break ratio and the length of the break period but prolongs the length of the make period. As will be seen later this type of distortion occurs on short lines of low insulation resistance and hence is often known as "short line distortion."

(*b*) Distortion which increases the break ratio and the length of the break period but reduces the length of the make period. This form of distortion is the type experienced on long lines of high resistance and hence is often known as "long line distortion."

The terms "long line distortion" and "short line distortion" are in some respects misleading. Whilst they are descriptive of the conditions obtained on the comparatively short lines between the subscriber's instrument and the exchange, they do not give a correct impression of the type of distortion to be expected on a long junction line with a high wire-to-wire capacitance. If the capacitance of the dialling circuit is high, then it is quite possible to obtain so-called short line distortion on a long high resistance junction circuit! The reasons for this will be apparent later but in the meantime it is important to visualize the two basic forms of distortion which may occur, i.e. reduced break distortion and reduced make distortion. The author prefers "+" and "−" to describe increased and reduced break distortion respectively—but this convention is not in general use. It should be noted that distortion can occur only in respect of impulse ratio. The impulse frequency cannot be changed during transmission except by some more or less elaborate arrangement of impulse regeneration.

It is clear from the above that the design of the impulsing relay and the resistance, capacitance and inductance of the circuit between the dial and impulsing relay all have their effect on the degree of impulse distortion. The combined effect of all the various constants is sometimes somewhat complex, but in the following paragraphs the more important factors are considered separately for the purpose of analysis.

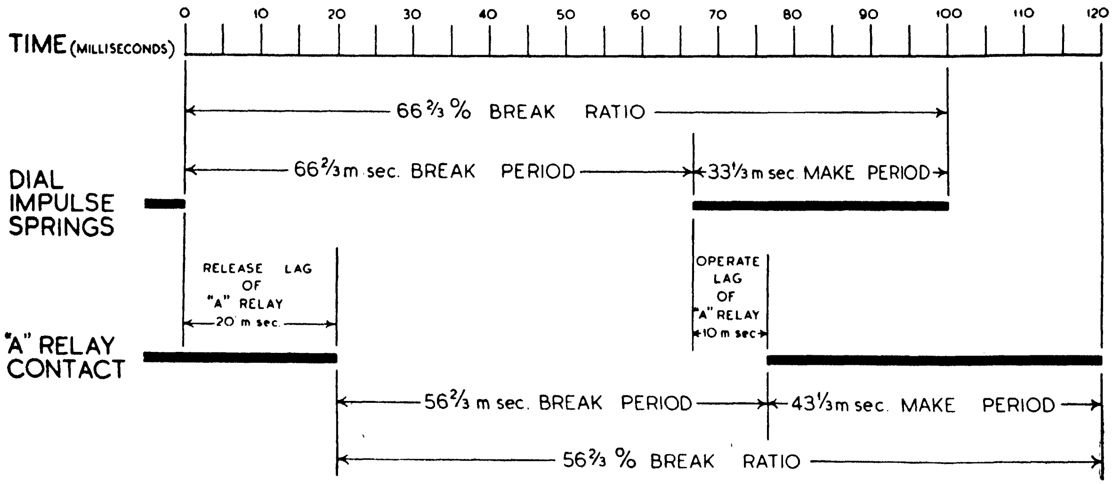


FIG. 193. SHOWING IMPULSE DISTORTION DUE TO UNEQUAL OPERATE AND RELEASE LAGS OF IMPULSE ACCEPTING RELAY

Impulsing Relay Performance. Although the electrical constants of the line have a material influence upon the operate and release lags of the impulsing relay, it is desirable to examine in the first place the characteristics of the relay itself without the effects of the intervening line. Fig. 194 shows the variation of flux in a typical impulsing relay when connected to a dial of normal impulse ratio. It is assumed that the *A* relay attains its maximum flux before the dial springs open for the first impulse. At the commencement of the first break, the current in the impulsing relay (shown by the broken lines in Fig. 194) falls to zero more or less instantaneously. The rapid decay of current induces an e.m.f. in the core and solid metal parts of the relay to produce eddy currents which maintain the flux for a period after the cessation of the energizing current. The rate of decay of flux on break is determined almost wholly by the extent of the eddy currents. If the eddy currents are high, then the decay of flux is more or less gradual,

whereas, conversely, a relay designed to minimize eddy currents will have a comparatively high rate of flux decay. In any case, there is a release lag between the moment of disconnexion and the time when the flux falls to the release value for the relay. This time is shown as R_1 in Fig. 194. It is clear that the release lag can be minimized by reducing the eddy currents and by making the release flux as high as possible.

At the re-closure of the dial contacts after the first impulse, the current in the relay coil commences to rise in accordance with Helmholtz's equation, but the rise of flux lags somewhat behind net result is a shortening of the first break impulse of a train.

First impulse distortion can be minimized by designing the A relay so that the rise of flux is sufficiently rapid to approach the maximum value during the make period between impulses. Unfortunately the impulsing relay is in most cases also the transmission bridge relay and is bridged across the speaking pair. The transmission requirements necessitate a relay of high impedance and hence of high inductance; conditions which are diametrically opposite to the characteristics required for good impulsing.

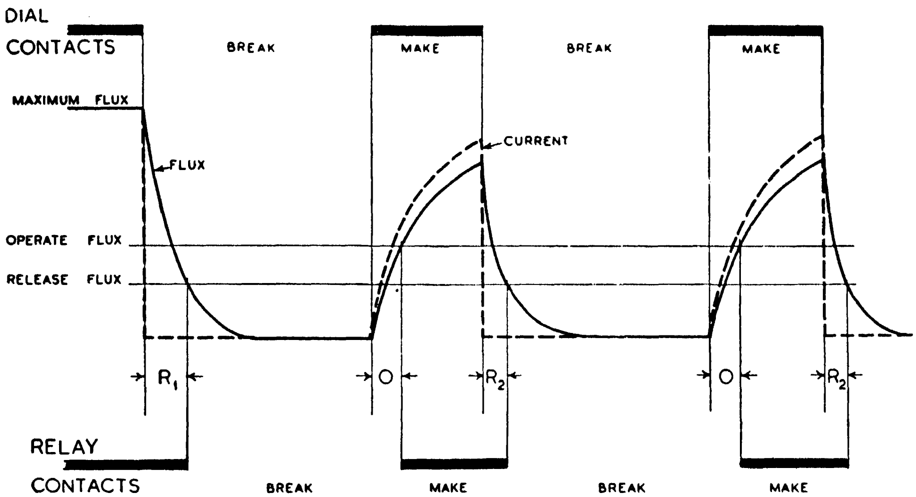


FIG. 194. FIRST IMPULSE DISTORTION DUE TO HIGH INDUCTANCE OF IMPULSING RELAY WHICH PREVENTS FLUX FROM ATTAINING MAXIMUM VALUE BETWEEN SUCCESSIVE IMPULSES

the current due to eddy current effects. If the time constant (L/R ratio) of the circuit is appreciable, the current cannot attain its maximum value before the circuit is again disconnected at the commencement of the second break period. Moreover, the effective flux of the relay is still further reduced by the eddy currents which at the moment of break are still appreciable. The net result is that the maximum flux at the end of the interval between the first and second impulses is lower than the initial maximum flux in the A relay. During the second break period the flux decays as before, but the lower initial value allows the flux to reach the release condition in a shorter time. As a result, the release lag of the A relay on the second and subsequent impulses is shorter than the release lag at the commencement of the first impulse. In Fig. 194 the first impulse release lag is shown as R_1, whilst the release lag for subsequent impulses is indicated by the smaller value R_2. The

It should be noted that, apart from transmission requirements, the inductance of any given relay depends upon the square of the turns. The tractive force of a relay depends upon the square of the ampere-turns. An impulsing relay is usually required to work in series with a subscriber's line and hence the available current is fixed between definite limits. It follows that the number of turns (and the resulting value of inductance) is largely governed by the tractive force required. The ideal relay (from an impulsing point of view) is one in which the minimum number of ampere-turns is required to operate the contact springs and where the eddy currents are as small as possible. By this means, a rapid rise and decay of flux can be obtained which not only reduces the value of the operate and release lags but, what is more important, it minimizes the *variation* of lag when the relay is connected in circuits of different electrical characteristics. The Siemens high-speed relay

described in Vol. I is much more efficient as an impulse repeating relay than the usual 3000 type, but its low impedance necessitates the use either of a transformer type transmission bridge or some device for increasing the impedance of the relay circuit after the completion of impulsing.

Before leaving Fig. 194 it is of interest to note how the operate lag of a relay depends upon the ratio of its operate current to the maximum circuit current. If the operate current is low as compared with the maximum current, then the relay operates on a comparatively steep part of the current/time characteristic. Hence, the inevitable variations of operate current value due to relay adjustments, etc., have little effect on the resulting operate lag. If, on the other hand, the maximum circuit current is only slightly above the operate current, the relay is working on a flatter portion of the characteristic and even small changes in operate current value produce quite appreciable differences in the operate lag. The same considerations apply to the release conditions, but in this case the minimum variation of release lag occurs when the release current most nearly approaches the maximum circuit current.

The adjustment of the contacts of an impulsing relay has, in certain circumstances, a material effect upon the degree of impulse distortion. In most circumstances the contacts of an impulsing relay are of the make-before-break type (i.e. K contacts), and, if the relay is adjusted to have a large contact clearance between the make springs, it tends to increase the operate lag and decrease the release lag. Conversely, a small (make) contact clearance results in a reduction of the operate lag and a corresponding increase of the release lag. Although the use of a make-before-break contact unit for impulsing eliminates the changeover time of the contacts, it may under certain circumstances introduce other difficulties due to prolonged bunching of all three contact springs during operation and release. This is particularly noticeable when the relay is operated in series with a high inductance such that the rise of current (and hence of tractive force) is slow. This aspect is considered in more detail later in connexion with the seizure (i.e. pick-up) of a selector circuit.

Impulsing Relay with Ballast Resistor. It has already been explained that impulsing relays often form the impedance elements of the transmission bridge which supplies current for the energization of the subscribers' transmitters. The use of ballast resistors to improve the volume efficiency of long lines has been discussed at some length in Volume I. The introduction of a ballast resistor necessitates the reduction of the transmission bridge relay from $200 + 200\,\Omega$ to $50 + 50\,\Omega$. In some cases the $50 + 50\,\Omega$ transmission bridge relay is the impulse accepting relay, and, owing to its lower resistance, has fewer turns than the ordinary type of impulsing relay. This results in a lower value of inductance and higher operate and release currents for the relay. The operate and release currents of the $50 + 50\,\Omega$ ballast resistor relay are of the order of 10 per cent greater than the corresponding currents necessary for the $200 + 200\,\Omega$ relay. At first sight it would appear that the higher current values of the ballast type relay would tend to increase the operate lag and reduce the release lag of the relay, thereby reducing the make period of impulses. The actual performance of the ballast resistor type relay does in fact produce the opposite effect, i.e. under given conditions it gives an impulse make period slightly longer than the make period obtained from a $200 + 200\,\Omega$ relay. The difference in performance is due primarily to the reduction in inductance and effective resistance of the $50 + 50\,\Omega$ relay which improves (steepens) the arrival and decay wave fronts.

From an impulse distortion point of view the ballast type relay is rather better than the non-ballast type, but the ballast type relay is somewhat more susceptible to transient current surges than the ordinary relay.

Isthmus Armatures. It is desirable that, generally speaking, the operate current of an impulsing relay should be as low as possible, whilst the release current should be made as high as possible. By this means, the operate and release lags are minimized, the relay is less susceptible to variations of adjustment and, what is probably most important, the operate and release lags of the relay are less dependent upon the electrical characteristics of the line. It is, of course, comparatively easy to reduce the operate current of a relay by reducing the spring load or by minimizing the armature travel, but these measures also result in a reduction of the release current of the relay. With relays of the 3000 type (and with other relays employing the knife-edge principle of mounting the armature) the release current is appreciably lower than the operate current, particularly when the spring load is light. As will be seen later, a low value of operate current is necessary to ensure satisfactory performance when the relay is connected to a line of high ohmic resistance. Unless special measures are taken, the resulting low release current value makes the relay very susceptible to the effects of line leakance, capacitance surges, etc. It is clear then that some device on the relay itself, which will increase the release current without at the same time appreciably

increasing the operate current, would be very beneficial.

In practice, all impulse accepting relays of the knife-edge type are fitted with special armatures, known as *isthmus armatures*. Fig. 195 shows two common types of isthmus armature. At (*a*) the armature is cut away at a point between the knife-edge and the relay core by two parallel-sided slots which materially reduce the cross-sectional area of the iron path through the armature. Design (*b*) (Fig. 195) produces the same effect by means of V-shaped slots cut into the sides of the armature. The main object of the isthmus armature is to increase the magnetic reluctance of the flux path by reducing the cross-sectional area of the iron path. The increase of reluctance reduces the flux-density in the armature air gap for a given number of ampere-turns in the winding. This results in some loss of tractive force during the operation of the relay, but the presence of the high reluctance of the armature air gap somewhat limits the effect of the isthmus. Under release conditions, however, the armature air gap is of lower reluctance and the isthmus has a much greater effect. The net result is an appreciable increase in the release current value with only a moderate increase in the operate current of the relay.

The principle can perhaps be illustrated simply by means of an electrical analogy. In Fig. 196 the magnetomotive force of the relay winding is replaced by a battery of voltage E_1, E_2, etc. The reluctance of the armature air gap is shown as a resistance of 10 Ω when the relay is normal and by a lower resistance of 2 Ω when the relay is operated. The reluctance of the restricted iron path at the isthmus is shown as 5 Ω. The reluctances of the remaining parts of the magnetic circuit are small in comparison and have been omitted for simplicity. In the upper portion of

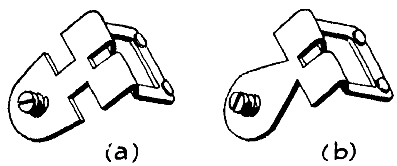


FIG. 195. TYPICAL ISTHMUS ARMATURES

Fig. 196 the operate flux of the relay is represented by current i_1, and the ampere-turns necessary to produce this operate flux are shown as E_1 and E_2 for the ordinary and isthmus armature conditions respectively. A simple application of Ohm's Law to the two circuits shows that during the operate condition, the introduction of the 5 Ω resistance necessitates a voltage (E_2) 1·5 times the normal voltage (E_1). This represents an increase of 50 per cent in the operate current of the relay. Under release conditions the battery voltage (E_4) must be 3·5 times the value of E_3, i.e. in the equivalent magnetic circuit the release current is increased

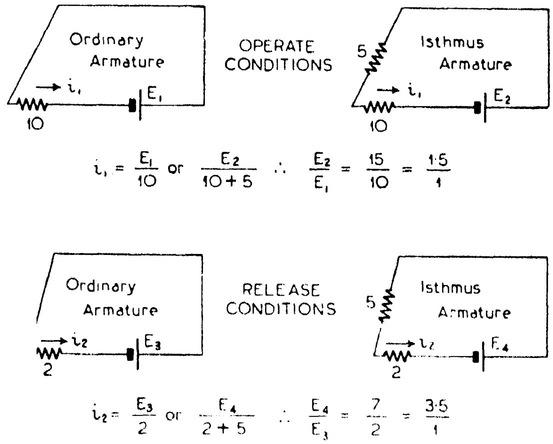


FIG. 196. ELECTRICAL ANALOGY TO SHOW THE EFFECT OF AN ISTHMUS ARMATURE

by 250 per cent by the introduction of an isthmus armature.

Although the main effect of the isthmus armature results from the increase in reluctance of the magnetic circuit, the magnetic restriction also modifies the value of leakage flux (i.e. the ratio of the total to the effective flux). The leakage ratio is, moreover, influenced by the permeability of the iron. The combined effects are somewhat complex, and it is found in practice that the shape of the cut-away portion of an isthmus armature has a material effect upon the performance of a relay. For the best results it is in fact desirable to design the armature for each type of relay coil and spring load. For purposes of standardization, however, the two types illustrated in Fig. 195 meet practical requirements. The isthmus armature with parallel-sided slots (Fig. 195 (*a*)) is used on the normal 200 + 200 Ω relay, whilst the pear-shaped armature (Fig. 195 (*b*)) has been designed for use with the 50 + 50 Ω relays used in conjunction with ballast resistors.

Fig. 197 shows the ampere-turn/armature-load characteristics of a 3000 type relay when fitted with ordinary and with isthmus type armatures. The full lines indicate the operating conditions, whilst the broken lines show the release characteristics. The lower tractive force of the isthmus armature relay for a given value of current in the coil is primarily due to the added reluctance of the isthmus armature. It should be noted, however,

that the tractive force is proportional to the square of the flux-density in the air gap, and hence any difference in flux-density produced by the inclusion of an isthmus produces a much greater divergence of the curves for the tractive force. If, for example, it is assumed that the armature load with the relay normal is, say, 30 g, the operate current is indicated by point A in Fig. 197. The introduction of an isthmus armature increases the operate current to value B. Once the relay has operated,

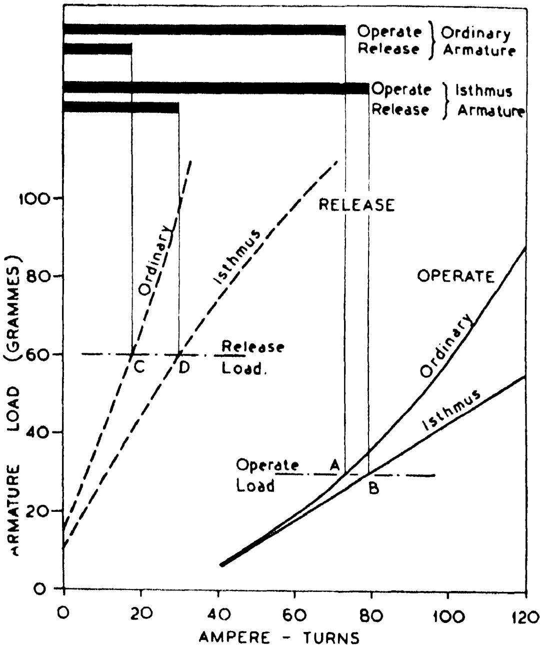


FIG. 197. ARMATURE LOAD/AMPERE-TURNS CHARACTERISTICS OF RELAYS WITH AND WITHOUT ISTHMUS ARMATURES

the armature load is appreciably increased due to the build-up of spring pressure. Assume, for convenience, that the armature load during release is 60 g, then the release current with an ordinary armature is shown by point C, whilst the release current for an isthmus armature is given by point D. It is clear that the *proportional* increase of release current is much greater than the corresponding increase of operate current. This comparison is not strictly true owing to the fact that the build-up of tractive force as the armature operates is less with an isthmus armature than with an ordinary armature. The apparent armature load during operation for a given spring set is therefore somewhat less when an ordinary armature is fitted. Nevertheless, the conditions illustrated in Fig. 197 are substantially borne out in practice. For instance, a 3000 type relay with one K contact *unit and an ordinary armature requires 62 ampere-turns to operate, and releases when the energization falls to* 18 ampere-turns. The comparable figures for an isthmus armature relay are 85 and 29 ampere-turns respectively, i.e. the fitting of an isthmus armature increases the release current by 61 per cent for a rise of 37 per cent in the value of the operate current. It will be noted from Fig. 197 that the greatest benefits can be obtained from the use of isthmus armatures when the ratio of the release load to the operate load is made as great as possible.

The employment of isthmus armatures is not without its disadvantages. The introduction of the high reluctance in the magnetic circuit of an impulsing relay makes the relay more susceptible to magnetic interference from other nearby relays. This effect is appreciable, and it has been found in practice that the operate and release lags of the impulsing relay may be increased by as much as 40 per cent due to flux leakage—particularly from the B and C relays which are generally adjacent to the impulsing relay. Unfortunately the effect of flux leakage renders the impulsing relay's performance somewhat variable due to the changing conditions of the surrounding relays during the setting up of a call. It is therefore now standard practice to fit a magnetic shield over all impulsing relays fitted with isthmus armatures. The shield is of mild steel some 90 mils thick and is of channel shape to clip over the relay coil. The shield itself does, of course, have some effect on the impulsing relay. In the first place it increases the inductance and effective resistance slightly and reduces the operate current by about 10 per cent. It has also a very slight effect on the release current which is reduced by about 2 per cent.

Effect of Line Resistance. The ohmic resistance of the line between the subscriber's dial and the impulsing relay at the exchange has a material effect upon the faithfulness of the impulses repeated to the selector magnet. As the line resistance is increased, the maximum value of the current in the impulsing relay is correspondingly reduced and, what is more important, the rate of current growth during the operation of the relay is also reduced. In any inductive circuit the back e.m.f. due to the rise of current plus the voltage drop in the resistance of the circuit must at any instant be equal to the applied voltage, i.e.

if E = the applied voltage (volts),
R = the resistance (ohms),
L = the inductance (henrys),
i = the instantaneous current (amps),
t = time (seconds),

then the rate of change of current at time t sec is di/dt and the back e.m.f. of the inductance is $L\,di/dt$. Hence the equation for the circuit is:

$$E = L\frac{di}{dt} + Ri \quad . \quad . \quad (1)$$

from which

$$\frac{di}{dt} = \frac{E - Ri}{L} \quad . \quad (2)$$

If i is assumed to be the operate current of the relay (a constant for a particular relay) then, if E and L are also constant, an increase of R reduces the rate of current rise with the result that the operate lag is correspondingly increased. It should be noted from equation (2) that a lowering of the battery voltage has the same effect as an increase in the line resistance.

On release of the relay, the rate of flux decay is determined almost wholly by the eddy current effects, which are in turn dependent upon the maximum value of flux in the relay. As the line resistance is increased, the maximum value of flux

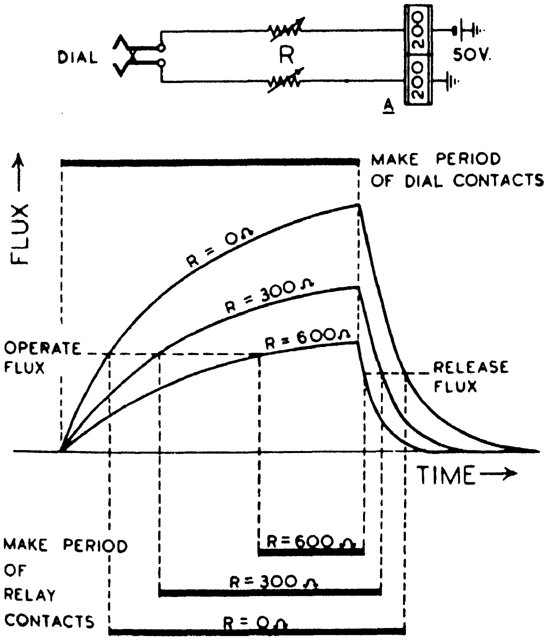


FIG. 198. IMPULSE DISTORTION DUE TO LINE RESISTANCE

is less, and hence the flux decays more rapidly to the release value for the relay, thereby reducing the release lag.

The above effects are illustrated diagrammatically in Fig. 198. On long lines the increase of the operate lag and the reduction of the release lag both curtail the length of the make period of an impulse. This results in a correspondingly long

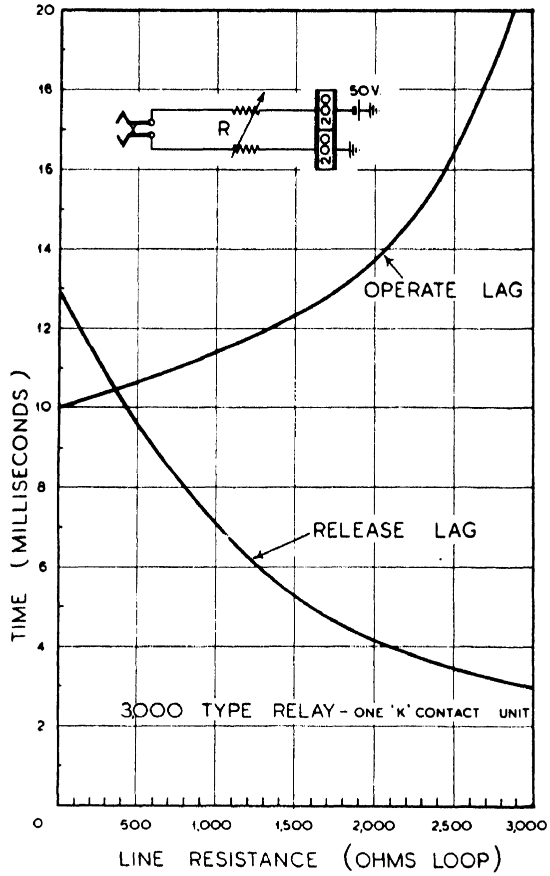


FIG. 199. OPERATING AND RELEASE LAGS WITH VARIOUS VALUES OF LINE RESISTANCE

break period and a high break-to-make ratio. It can be said then that the ohmic resistance of a line produces distortion which increases the effective break ratio of the impulses transmitted to the selector. It will be observed from Fig. 198 that as the line resistance is increased beyond a certain point, the operate lag grows rapidly. This is due partly to the general shape of the current/time characteristic and partly to the increased effect of the eddy currents when the curve is less steep.

Fig. 199 shows the operate and release lags obtained with a typical impulsing relay when connected to a non-reactive line of variable resistance. The sharp rise of operate lag at the higher values of line resistance will be noted. It will also be seen that at low values of line resistance the release lag is greater than the operate lag, but

on lines in excess of about 350 Ω the length of the operate lag predominates. The degree of distortion is determined by the difference between the operate

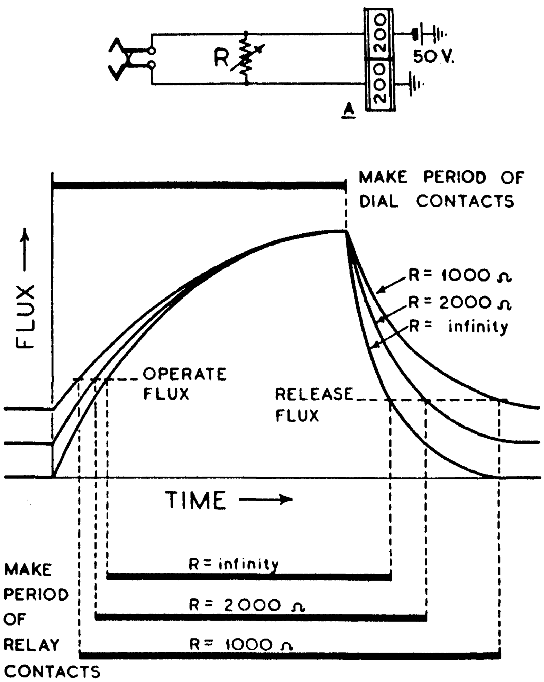


FIG. 200. IMPULSE DISTORTION DUE TO LINE LEAKANCE

and release lags. If, therefore, the relay is designed so that its operate and release lags are equal when applied to a line of average resistance, there will be a minimum of impulse distortion throughout the practical working range.

The operate and release lags given in Fig. 199 are the static values for the relay, i.e. the release lag as measured after the flux has attained its maximum value. It has already been seen that these conditions may not obtain in practice except during the first impulse. On all but the first impulse there may be insufficient time during the make period of the dial contacts for the relay flux to attain its maximum value, and the release lag is consequently somewhat shorter. Apart from this factor, there are, as will be seen later, a number of other considerations which have a material influence upon the operate and release lags of an impulsing relay, and hence the conditions shown in Fig. 199 do not show the actual performance of the relay during the repetition of a train of impulses.

Effect of Leak Resistance. Imperfect insulation of the external lines produces wire-wire and wire-earth leakage currents. Such leak currents provide a residual current in the impulsing relay when the dial springs open and thereby increase its release lag. The release lag is further increased, especially at low values of leak resistance, by the slugging effect of the leak resistance across the impulsing relay coils. When the dial springs close at the end of a break impulse, the relay is already partially fluxed due to the leakage current, and less time is therefore required for the flux to reach the operate value of the relay. By shortening the operate time and prolonging the release time, line leakage has the effect of lengthening the make period and shortening the break period of impulses. High battery voltage aggravates the distortion produced

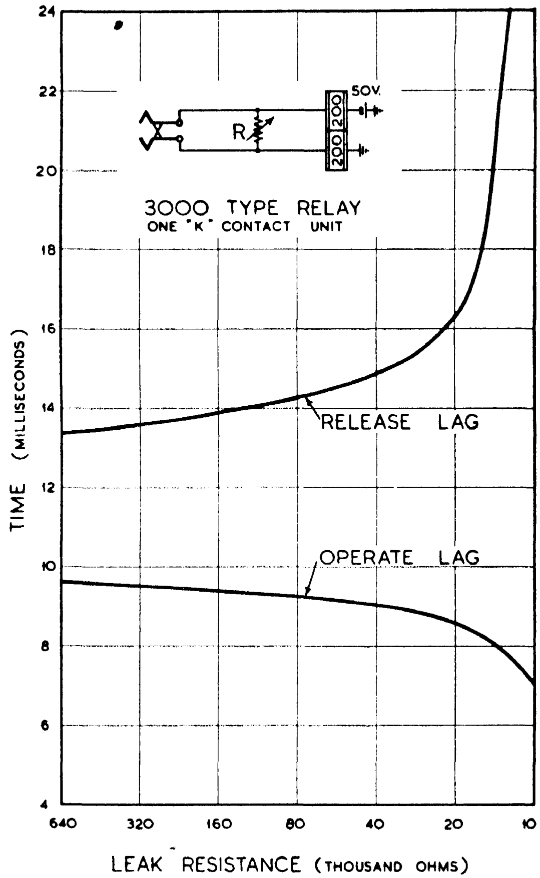


FIG. 201. EFFECT OF LINE LEAKANCE ON THE OPERATE AND RELEASE LAGS OF AN IMPULSING RELAY

by a given leak resistance. The reduction of break ratio on leaky lines produces, it will be noted, a form of distortion which is opposite to that obtained on lines of high ohmic resistance.

Fig. 200 illustrates the effect of line leakage on the performance of an impulsing relay. Somewhat

low values of leak resistance have been assumed in order to clarify the diagram. It will be seen that, whilst the effect of leak on the operate lag is not very great, the release lag increases very rapidly when the leak resistance is reduced beyond a certain point. This effect is shown somewhat more clearly in Fig. 201, which shows the operate and release lags of a sample relay when connected to a line of zero resistance with different values of leak. (The leak resistance is plotted on a logarithmic scale for convenience.) The operate lag of this particular relay decreases only by about 1 msec when the leak resistance is reduced from 640 000 Ω to 20 000 Ω, but, as the leak current approaches the operate current of the relay, the lag decreases somewhat to the point of failure at about 10 000 Ω. The release lag rises steadily as the leak resistance is reduced, but at about 40 000 Ω the lag increases at an ever growing rate as the leak current approaches the release current of the relay. It should be appreciated that the operate and release lags shown in Fig. 201 are the static lags of the relay and are not, for the reasons already given, the actual lags which would be obtained during the transmission of an impulse train.

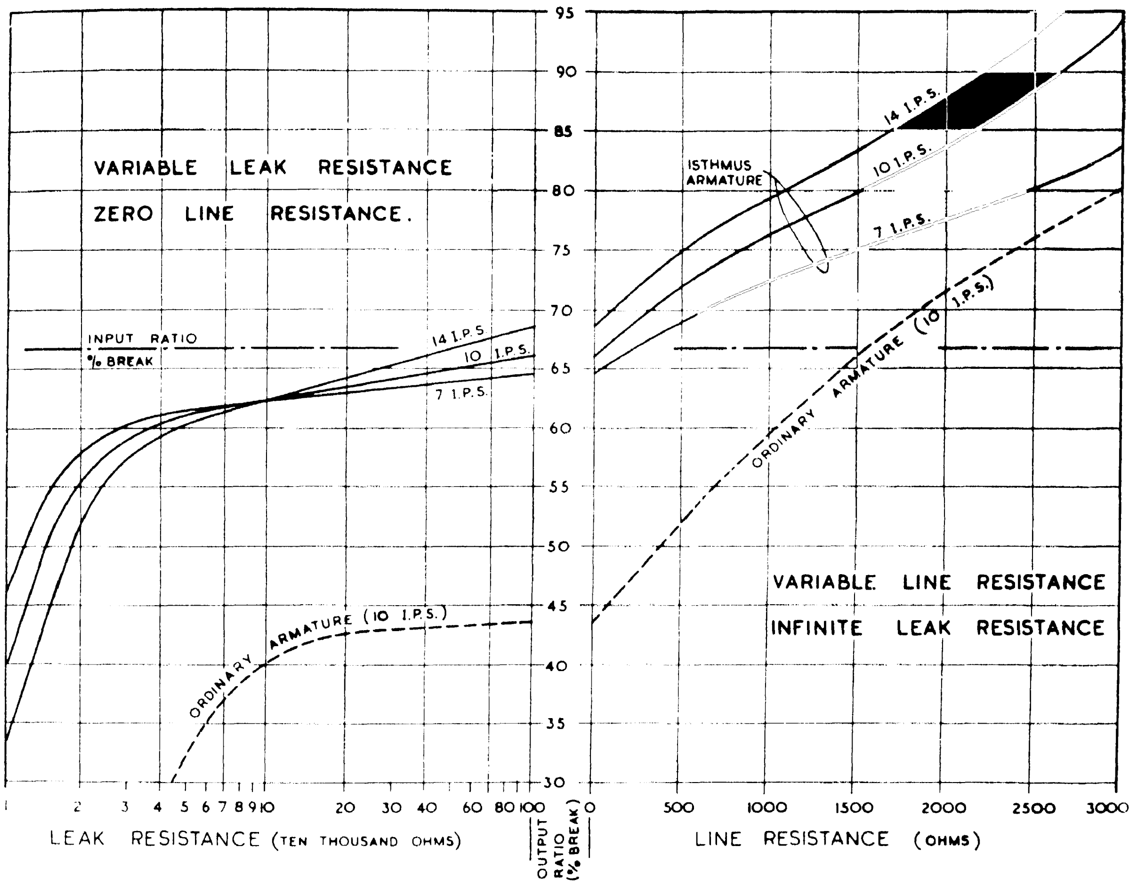


FIG. 202. IMPULSE DISTORTION UNDER VARIOUS CONDITIONS OF LINE RESISTANCE, LINE LEAKANCE, AND IMPULSE FREQUENCY

Ratio Distortion Due to Line Resistance and Leakance. It has been seen in the two previous sections that, as the ohmic resistance of the line increases, the operate lag of the impulsing relay becomes greater, whilst the release lag becomes shorter. The net result is an increase of the break ratio at the relay contacts. This effect is illustrated in Fig. 202 which shows the output ratio of a typical impulsing relay for various values of line resistance. The rapid increase of break ratio at high values of line resistance is clearly shown. The same illustration also shows how the output ratio is dependent upon the frequency of the incoming impulses. The higher the impulse frequency, the greater is the ratio distortion for any given value of

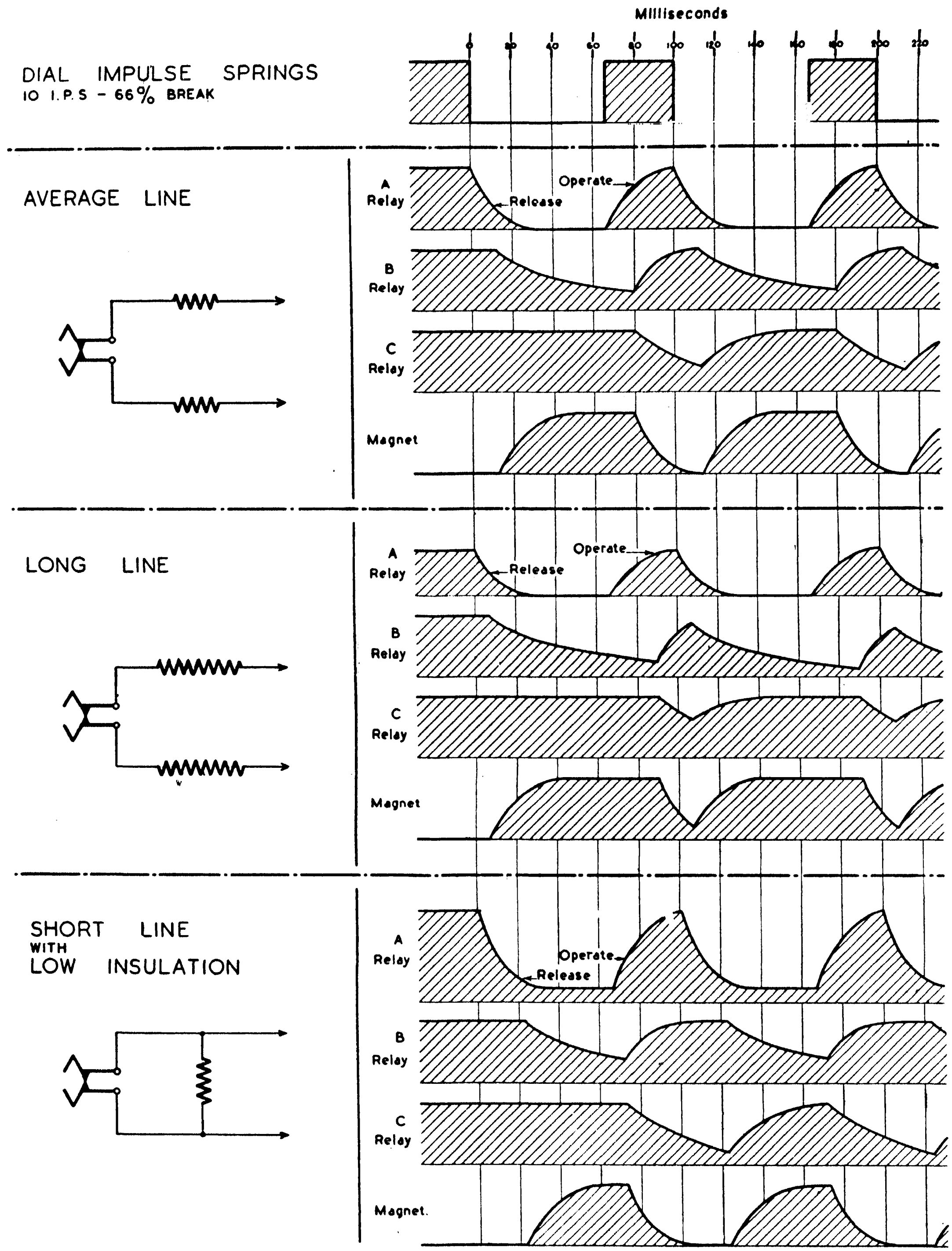


FIG. 203. CURRENT IN IMPULSING RELAYS AND SELECTOR MAGNET UNDER LONG LINE AND SHORT LINE IMPULSING CONDITIONS

line resistance. This is, of course, partly due to the shorter total impulse period at the higher frequencies and the consequent greater effect of a given difference between the operate and release lags. In addition, the higher the impulse frequency, the shorter is the period for which the relay is energized between impulses, with the result that the flux attains a lower maximum value and the subsequent release lag is correspondingly reduced.

It has been shown that leakance has the effect of decreasing the operate lag of an impulsing relay and increasing its release lag. The net result is a shortening of the break period and a reduction of the break ratio. The left-hand portion of Fig. 202 shows the results of practical tests of a typical impulsing relay. Whereas an increase of line resistance causes a steady rise in the output break ratio, the break ratio decreases only slightly as the leak resistance is reduced to about 40 000 Ω. Beyond this, the fall is more rapid and an increase of impulse frequency results in a lowering of the output break ratio. This is almost wholly due to the shorter impulse period at the higher frequencies. The lower maximum flux value between impulses in this case tends to compensate for the effect of the leak. Fig. 202 also shows the output ratio (under various line conditions) when the impulsing relay is fitted with an "ordinary" armature. A comparison of the curves shows how the isthmus armature reduces the degree of distortion on long or very leaky lines.

Fig. 203 shows the variation of flux in the A, B and C relays and in the magnet of an impulsing circuit. The top diagram shows the conditions obtaining on an average line, whilst the centre of the illustration shows the effect of long line distortion. The more onerous operating conditions of the B relay and the very short release period between successive energizations of the magnet are clearly shown. The lower part of the illustration shows the effects of distortion produced on short leaky lines. The holding flux in the C relay is now much reduced whilst the period for which the magnet is energized is shortened. It is clear that long line distortion is beneficial to the operation of the C relay, whilst short line distortion produces the most favourable conditions for the B relay.

Effect of Dial Spark Quench Capacitor. It was shown in Volume I that a spark quench circuit is necessary across the impulsing contacts of the subscriber's dial to prevent the development of high induced e.m.f.s in the line resulting from the self-inductance of the impulsing relay at the exchange. Without such a spark quench capacitor, the life of the dial contacts is appreciably shortened and the high line voltages tend to produce disturbance in adjacent conductors and even the possibility of breakdown of the insulation. The usual spark quench circuit (of subscribers' instruments) is a 2μF capacitor and a non-inductive resistor of the order of 30 Ω connected directly across the dial impulsing contacts. Before the first break impulse, the dial contacts provide a short circuit across the spark quench circuit so that the capacitor is normally discharged. At the moment of break, the inductive energy of the impulsing relay is absorbed by the spark quench circuit and, at the same time, the spark quench capacitor commences charging to the 50 V exchange battery. When the steady state is reached, the potential across the capacitor is the same as the p.d. of the exchange battery. In due course the dial interrupter springs remake and the capacitor discharges through the circuit provided by the dial contacts. The 30 Ω resistor in series with the spark quench capacitor limits the initial amplitude of this discharge current to avoid local heating and the possibility of welding of the contacts.

The dial spark quench circuit has a material effect upon the operate and release lags of the impulsing relay and hence upon the degree of distortion introduced. Fig. 204 shows the effect when a quenched dial is applied to an impulsing relay through a line of negligible ohmic resistance. When the dial contacts open, the energy stored in the magnetic field of the impulsing relay produces a surge of current to charge the spark quench capacitor. This surge, in passing through the relay coil, tends to hold the relay and thereby decrease the break period. If there is little or no line resistance, the electrical constants of this circuit are such that the resulting current is oscillatory in character. (It has already been stated that such conditions occur if $R^2/4L^2 < 1/LC$.) The initial decay waveform of the current in the impulsing relay is less rapid with the spark quench capacitor, and hence the release lag is increased (X as compared with W in Fig. 204) and the length of the break period is shortened.

The oscillatory nature of the flux in the impulsing relay during release conditions may, under certain circumstances, produce split impulses or an excessive distortion of the impulse ratio. Fig. 204 shows a typical flux decay waveform under short line conditions. The current in the circuit is disconnected at point A when the dial springs open, and when the flux in the relay falls to the release value for the relay (C) the relay contacts restore. If, now, the relay is sufficiently sensitive it may re-operate at point D due to the heavy flux reversal resulting from the spark quench capacitor

surge. The relay subsequently releases again at point *E* to produce a short false make period. If the selector magnet is sufficiently sensitive, there is a danger that it may be operated during the short break period *Y*. Even if the duration of the break period *Y* is insufficient to operate the selector magnet, the re-operation of the impulsing relay during the flux reversal very considerably reduces the effective break period of the impulse. In effect, if the normal release lag of the relay is *X*, the re-operation during flux reversal produces conditions which are equivalent to those which would obtain if the release lag of the relay were *Z* (Fig. 204).

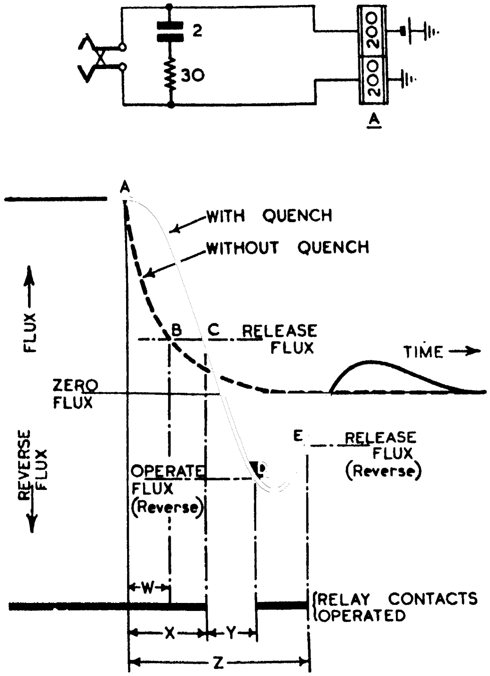


FIG. 204. EFFECT OF DIAL SPARK QUENCH CAPACITOR ON SHORT LINES

Effect of Spark Quench on Long Lines. When line resistance is present, it has a damping effect on oscillatory currents due to the spark quench capacitor, and the amplitude of the flux reversal is reduced. On long lines the capacitor discharge is no longer oscillatory and the flux in the impulsing relay decays logarithmically. These conditions are illustrated in Fig. 205 where the broken line shows the decay of flux without a spark quench capacitor and the full line shows the conditions with a capacitor across the dial contacts. It has already been seen that as the line resistance increases, the release lag of the relay tends to shorten. Under long line conditions, the less rapid decay of flux produced by the quench capacitor tends to prolong the release lag (*Y* as compared with *X*) and so compensates to some extent for the decrease of lag due to the ohmic resistance of the line. It has the effect in practice of making the output ratio less dependent upon the value of the line resistance. This compensating effect continues with increase in line resistance until the latter becomes so great that the operate lag of the relay increases rapidly and swamps the effects of the release lag.

Effect of Spark Quench on Leaky Lines. The dial spark quench capacitor has a somewhat complex effect when leakance is present. Fig. 206 shows a typical waveform for a moderate amount of leak. Generally speaking, the spark quench capacitor has very little effect on the release lag if the leakage current is not excessive. As the leakage current increases, it tends to make the circuit less oscillatory. The most important result of the spark quench capacitor is that, for any given value of leak, the rate of flux decay is steeper with than without the capacitor. (This is particularly so with the lower values of flux.) In Fig. 206 the portion *AB* of the flux decay curve is considerably

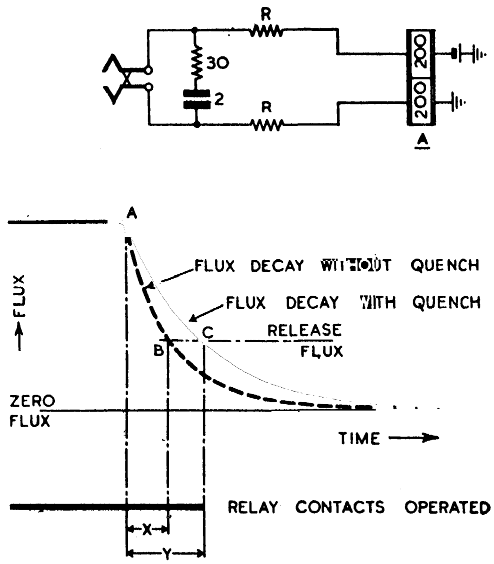


FIG. 205. EFFECT OF DIAL SPARK QUENCH CAPACITOR ON LONG LINES

less steep than the comparable curve *CD* for the quenched circuit. This is advantageous in that it makes the release lag of the relay less dependent upon the value of the release flux (i.e. less dependent upon relay adjustment). Moreover, as the leak current increases, the increase of release lag under

quenched conditions is less than the increase of lag without the spark quench capacitor. The capacitor does, therefore, make the release time of the impulsing relay more independent of the value of leak resistance. As the leak current increases, the circuit becomes less oscillatory and a point is reached when the capacitor has little effect in preventing the rapid increase of release lag.

Effect of Line Capacitance. All external lines possess, in addition to ohmic resistance, a certain value of capacitance. The capacitance between wires is greatest on pairs routed through underground cables and is much less where the lines are entirely overhead. The effect of this capacitance is somewhat similar to the effect described above for the spark quench capacitor in the subscriber's telephone. There is, however, one big difference. Whereas the value of capacitance in the spark quench circuit is the same irrespective of the length of the line, the capacitance of the line itself is directly proportional to the length of the circuit. It is therefore not possible to get a high value of capacitance on a short line. Generally speaking, it can be said that line capacitance has a negligible effect on the impulse distortion when the line is short. As the length of the line is increased, both the capacitance and the ohmic resistance increase. The capacitance tends to produce an oscillatory current at the moment of break, and the decay

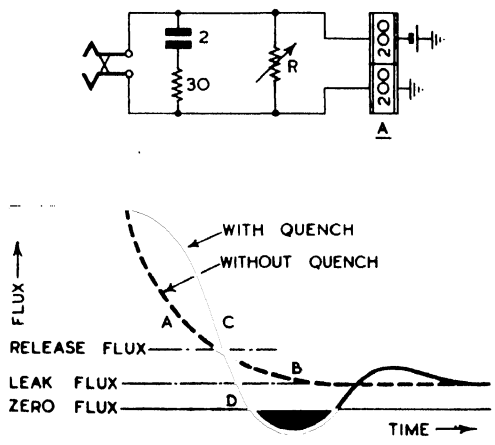


Fig. 206. Dial Spark Quench Capacitor on Leaky Lines

waveform is such as to prolong the release lag of the relay. (As the line charges to battery potential, the resulting current tends to hold the impulsing relay.) The line resistance, on the other hand, tends to reduce the value of the release lag and increase the operate lag. Hence line capacitance has the effect of neutralizing to some extent the "increased-break" distortion resulting from the ohmic resistance of a long line.

Unlike the dial spark quench capacitor, line capacitance produces some slight effect when the

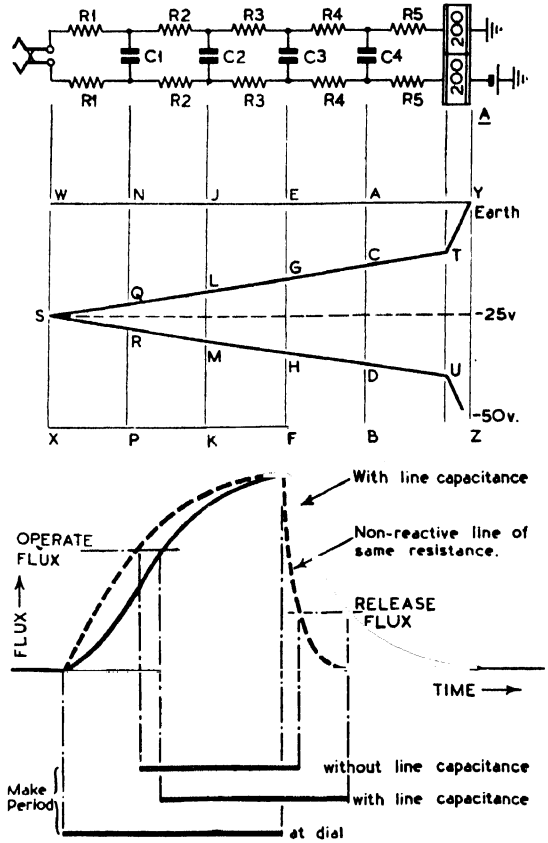


Fig. 207. Prolongation of Make Period Due to Line Capacitance

dial contacts remake at the end of an impulse. In considering the dial spark quench circuit it can be assumed that the whole of the charge held by the capacitor is dissipated through the short circuit provided by the dial impulse contacts, and does not affect the growth of current in the impulsing relay. The wire-to-wire capacitance, however, is spread over the whole length of the line and, for purposes of analysis, can be considered as a large number of small capacitors connected together by elements of line resistance. In Fig. 207 the conditions are shown by a series of resistors (R) and capacitors (C) such that the total resistance of the various elements is equal to the total loop resistance of the circuit, and the total value of all the small line capacitors in parallel is equal to the total wire-to-wire capacitance. When the dial springs

are open, one line is at earth potential (WY) whilst the remaining line is at a potential 50 V negative to earth (XZ). At the end of the impulse (i.e. when the dial springs close) both lines are brought to the same potential (S) at the dial contacts. The line capacitance near the subscriber's telephone ($C1$) now commences to discharge through the impulsing contacts, thereby lowering the potential across $C1$. This in turn allows $C2$ to commence its discharge, whilst the consequent reduction of potential at $C2$ permits the discharge of $C3$. This process continues along the line until the steady

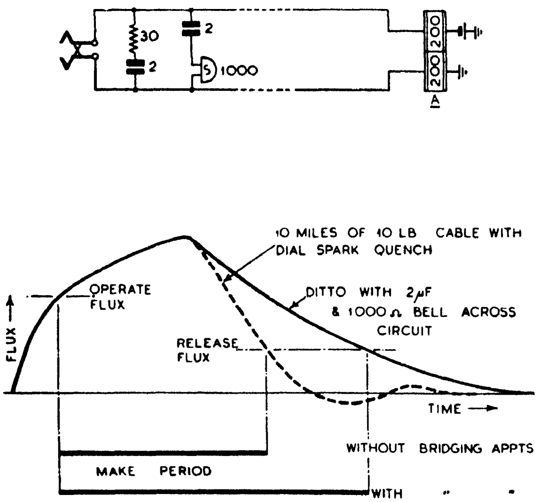


Fig. 208. Prolongation of Impulse Make Period Due to Bridging Apparatus

state is reached when there is a uniform fall of potential ($I \times R$) throughout the circuit which can be represented by the line $YTSUZ$ in Fig. 207. It should be noted that each line element discharges towards the subscriber's end of the circuit and that no discharge currents traverse the impulsing relay. The line capacitance does, however, introduce a delay in the change of potential at the relay coils and thereby increases the operate lag of the relay. The total results are illustrated in the lower part of Fig. 207 which shows how both the operate and the release lags are increased by the presence of line capacitance. It has been assumed in Fig. 207 that the line constants are such as to produce non-oscillatory conditions. If the conditions are oscillatory, the problem is much more complex and there may actually be some boosting of the wavefront at the impulsing relay.

Effects of Bridging Apparatus. It is important to consider the effect on impulse distortion of any apparatus bridged across the impulsing loop. Any bridging apparatus which provides a d.c. path is, of course, not permissible. The effect of a capacitor across the impulsing relay has already been considered in relation to the dial spark quench circuit and the line capacitance. Usually the presence of capacitance produces the oscillatory form of flux decay already considered, but the amplitude of the oscillation, its frequency and the degree of damping are determined by the relative values of inductance, capacitance and resistance. It is therefore not easy to predict the effect of a capacitor bridged across the impulsing loop without a careful examination of the remaining electrical constants of the circuit. Apart from line capacitance and the dial spark quench capacitor, it sometimes happens that the series line capacitors which form part of a capacitor-impedance transmission bridge are placed across the impulsing circuit. This aspect is considered later in connexion with impulse repetition.

Conditions sometimes occur in practice where a bell and capacitor are connected across the speaking conductors during impulsing. This occurs, for example, when a call is being set up from the extension instrument on a Plan 7 installation with a Bell Set 20 (see Volume I). Such conditions give rise to very severe impulse distortion. Fig. 208 is based upon actual oscillograms of the current in the impulsing relay both with and without a bridging bell circuit. It will be seen that the 1000 Ω magneto bell and the 2 μF capacitor in series produce a very gradual decay of current instead of the more rapid oscillatory waveform when the bell circuit is omitted. The net result is a much prolonged release lag and a correspondingly low break ratio.

The effect on impulsing performance of a bell circuit across the impulsing loop is so serious that most modern circuits avoid this condition wherever possible. In the Plan 7 case, the new Bell Set No. 39 is expressly designed to remove the magneto bell circuit from the line during dialling from the extension instrument.

Combined Effects. In the preceding paragraphs consideration has been given to the effect of various electrical conditions upon the impulsing performance of a circuit. It is interesting to summarize these effects by analysing the impulse distortion produced under various practical conditions. The curves of Fig. 209 show the output at the contacts of an impulsing relay with a constant input frequency of 10 I.P.S. with a break-to-make ratio of 2 : 1. The output ratio is shown for various values of line resistance and when the relay is connected through different lengths of typical underground cable. Curves A, B, C and E are artificial in that they show the effect of leak and the addition of a spark quench capacitor to a

non-reactive line. Curves D, F and G show typical test results when the impulsing relay is connected through an underground cable with conductors of 10 lb per mile. The effect of line capacitance in minimizing the rise of break ratio due to the resistance is clearly shown by curves C and D. The effect is even more marked when line leakance is present as in curves E and F. Fig. 209 also shows how leakance very materially reduces the output break ratio at high values of line resistance—(compare curve D with curve F). The very important effect of bridging apparatus is shown by curve G. In this particular test the presence of a 2 μF capacitor

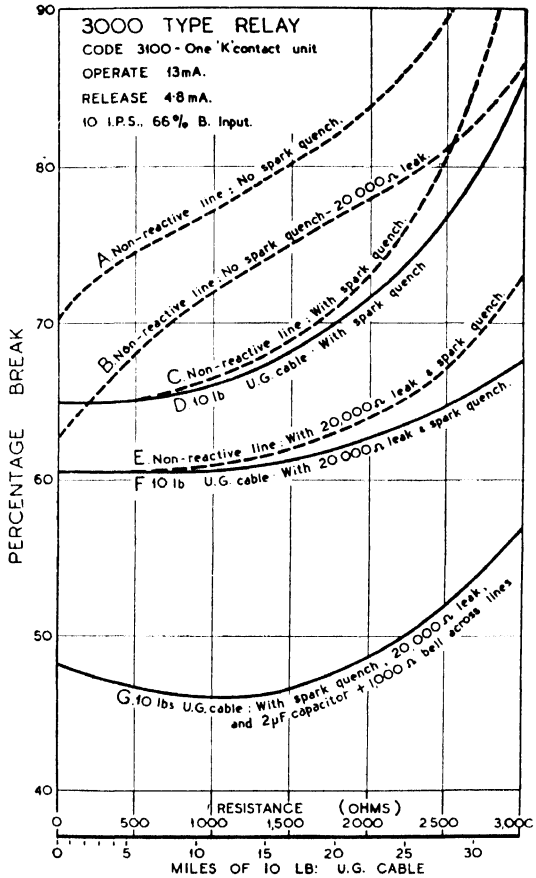


FIG. 209. IMPULSE DISTORTION UNDER VARIOUS CONDITIONS WITH NON-REACTIVE AND REAL LINES

and 1000 Ω bell in series across the impulsing loop may reduce the output break by as much as 15 or 20 per cent for a given value of line resistance—(compare curve D with curve G).

Measurement of Impulse Frequency and Impulse Ratio. We have seen that the impulse frequency and impulse ratio have an important influence upon the performance of an automatic switching system. On the one hand, it is necessary to ensure

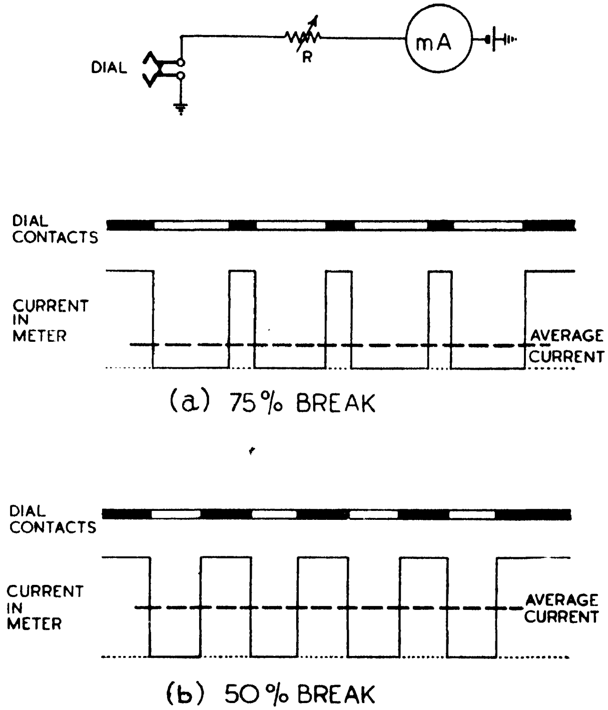


FIG. 210. SIMPLE CIRCUIT FOR THE MEASUREMENT OF PULSE RATIO

that the dials of the subscribers' instruments are correctly adjusted to give impulse trains which are within specified limits both of frequency and of ratio. In addition, it is sometimes necessary to measure the ratio of impulse trains repeated at various points in the exchange switching system. Testers are provided as part of the normal Test Desk equipment for the measurement of impulse frequency. These testers (described in Vol. I) enable impulse frequency tests to be made of the subscribers' dials *in situ*. No provision is made for testing the ratio of the impulses transmitted by the subscriber's dial, reliance being placed on the adherence to close limits in the mechanical adjustments of the dial impulsing contacts.

There is a number of ways in which the impulse frequency and impulse ratio can be measured electrically. Some of these methods involve the use of electronic devices or cathode-ray oscillographs. For most purposes, however, sufficiently accurate measurements can be obtained by the use of the simple circuit arrangements illustrated in Figs. 210 and 211.

Fig. 210 shows how a suitable milliammeter can be used to measure impulse ratio. The impulsing contacts are connected in series with the milliammeter, a suitable battery and a variable resistor *R*. The resistor is adjusted so that, when the impulsing contacts are closed, the milliammeter gives a reading of 100 divisions. If a long train of impulses is now transmitted, the pointer of the milliammeter will take up a position which is approximately proportional to the average value of the current through it. If, for example, the impulse ratio is 50 per cent break, the needle of the meter will read 50 divisions and, similarly, if the impulsing contacts are giving a 66 per cent break the meter will read 33 divisions. At low impulsing speeds there may, with some instruments, be a tendency for excessive vibration of the needle during impulsing, but this can be avoided by the use of a heavily damped movement.

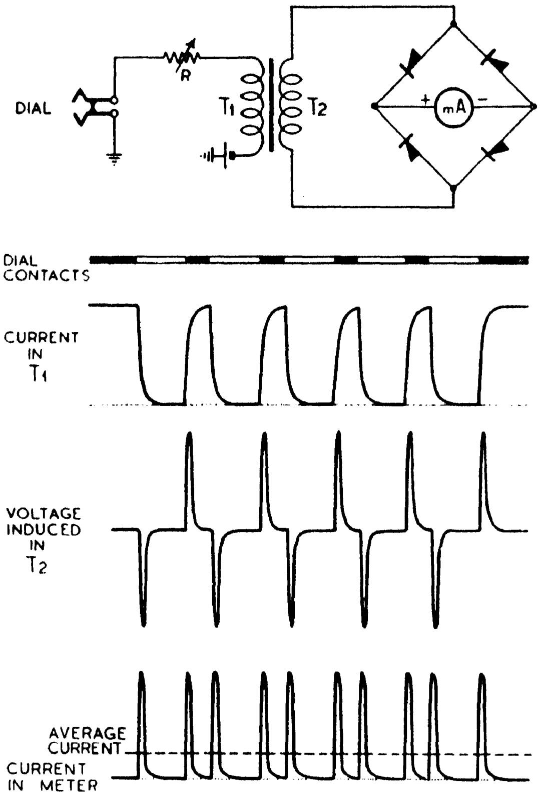


FIG. 211. METHOD OF MEASURING IMPULSE FREQUENCY

The average current reading of the meter represents the make ratio of the impulses only when the impulses themselves are square topped. Hence the circuit cannot be used where the current takes some time to attain its maximum value and decays slowly at the end of the impulse. The circuit is unsuitable for the measurement at the exchange of the impulse ratio of dials in a subscriber's premises. Moreover, when measuring the impulses from an ordinary dial, it is not possible to obtain more than 10 impulses in a continuous train. This means that there is very little time for the needle of the meter to reach a steady position before the end of the impulse train. The difficulty can be minimized by providing a preset circuit for the milliammeter which is so arranged that the needle of the meter is held in the approximately correct position prior to the receipt of the impulse train. Such a preset circuit requires a relay to change over the meter from the preset circuit to the impulsing circuit at the commencement of the train.

Fig. 211 shows a method of measuring impulse frequency. The impulsing contacts are connected to the primary winding of a transformer *T*, the secondary of which is wired to a suitable milliammeter via a bridge rectifier network. There is no current through the meter nor in the secondary circuit except when there is a *change* of current in the primary circuit. When the impulsing contacts close, the current builds up quickly in the primary of the transformer, and this change of current gives rise to a pulse of current in the secondary circuit which dies away when the primary current reaches a steady value. At the end of the make period of an impulse, the cessation of the current in the primary winding causes a similar (but reversed) surge of current in the secondary circuit. The rectifier bridge converts the alternating secondary pulses to unidirectional pulses of current through the milliammeter. Under any given conditions, the pulses of current through the meter are independent of the ratio of the impulses. Hence the mean current in the milliammeter is proportional to the number of surges in a given time, i.e. it is proportional to the impulse frequency. The meter can be calibrated to give direct readings of impulse frequency.

As with the previous circuit, the arrangements shown in Fig. 211 cannot be used when the impulsing contacts are separated from the rest of the circuit by a line which may have various values of resistance and capacitance. Changes in the line characteristics affect the maximum value of the current in the primary winding and also the rate of change of this current at the beginning and at the end of each impulse. As before, it is necessary to have a preset circuit for the milliammeter when measuring the impulse frequency of a short train such as is given by the standard dial.

Provided that the limitations of the above two circuits are borne in mind, they are extremely useful for the measurement of the frequency and ratio of impulses generated by various devices such as dials, impulse machines, impulse regenerators, and similar apparatus.

EXERCISES V

1. Most automatic selector circuits require a signal to indicate when each impulse train is completed. Show how the signal is obtained and explain why it is necessary to have such a signal.

2. Explain how variations of frequency and ratio at the impulsing contact of a selector affect the performance of the *B* and *C* relays and of the magnet. The following defects were observed on three separate switches during tests of a number of 2-motion group selectors:

(*a*) Wipers stepped to level 0 when 9 was dialled.

(*b*) Wiper carriage restored to normal during receipt of a long impulse train.

(*c*) Wipers cut-in on level 8 when 9 was dialled. Describe the possible causes of these failures.

(It may be assumed that the dial of the testing instrument is in good adjustment.)

3. What are the advantages of using "short-circuited" *B* and *C* relays in a selector circuit? Metal rectifiers are sometimes used with *B* relays of the slugged type. Why is this?

4. Draw a diagram showing the connexions of the relays and magnets that control the movements of the wipers of an ordinary final selector. If the last two digits of a called subscriber's number were 34, how would the required movements of the wipers be effected? (*C. & G. Telephony, Grade I*, 1938.)

5. What is impulse distortion, and how is it affected by the conductor resistance and insulation resistance of the subscriber's line? What is the result when a high line resistance and a low insulation resistance occur simultaneously?

6. What characteristics are desirable in an impulse accepting relay? Why are "isthmus" armatures often fitted to such relays?

7. Discuss the effects of line capacitance on the performance of an impulsing circuit. How are these effects modified if there is:

(*a*) a high conductor resistance,

(*b*) a low insulation resistance?

8. What is the purpose of the capacitor and resistor fitted across dial impulsing contacts? How do they affect the impulsing performance of the circuit?

9. When a call is made from an extension instrument of a P.B.X., a capacitor and an indicator are often connected in series across the pair during dialling. What is the effect of this bridging apparatus on the performance of the impulsing relay at the exchange?

10. Describe, with the aid of a simple diagram, a circuit suitable for measuring the impulse frequency of a subscriber's dial.

CHAPTER VI

IMPULSE REPETITION, STORAGE, AND REGENERATION

So far we have examined how the impulses from a subscriber's dial can be used to control the various movements of a step-by-step selector. In a modern telephone system there are many occasions when the digits dialled by the subscriber must be repeated at various points in the network before they are finally utilized in the selector impulsing circuit. On certain calls, the impulses may become so distorted during transmission that it is necessary to introduce devices for the correction or even the regeneration of the impulse trains.

In some cases (e.g. in the director system) the impulses from the subscriber's dial do not control the switch mechanisms directly, but are utilized as signals to special apparatus which, on receipt of a dialling code, sends out the appropriate trains of impulses to route the call to the required destination. In other circumstances, the digits dialled by the subscriber must be counted to determine the appropriate fee for the call.

It is the purpose of this chapter to examine these various impulse repeating circuits, impulse storage circuits, etc.

Impulse Repetition. When a call has to be set up through one exchange and over a junction route to a second exchange it is not usual to extend the 3rd conductor (the P-wire) for holding and control purposes, and hence it is necessary to provide a separate holding circuit for the switching train in each exchange. The provision of a holding circuit in turn necessitates a relay bridged across the line which can be controlled from the calling subscriber's cradle-switch. The introduction of this transmission bridge, in turn, requires the repetition of impulses from one side of the bridge to the other. The circuit arrangements are considered in detail later and for the moment we are interested only in the method of repeating impulses.

Basically, the repetition of impulses necessitates the provision of an impulse accepting relay on one side of the bridge and a pair of contacts associated with this relay on the other side of the bridge to repeat the impulses to line. It is clear that, unless the operate and release times of the impulse accepting relay are equal, then impulse distortion will occur at the point of repetition. Such distortion is additive (algebraically) to the distortion which occurs at the impulse accepting relay associated with the automatic selector.

The conditions are further aggravated when a second impulse repetition point is introduced, e.g. if a call is to be routed from one exchange through an intermediate exchange to a third exchange. In this case the resulting impulses to the selector magnet are subject to the cumulative distortion produced by three impulsing relays. The effect is illustrated in Fig. 212, which shows a call routed over two junctions. In this diagram it has been assumed that the operate lag of each A relay is slightly less than its release lag. The repeating contact $A2$ at the originating exchange therefore forwards over the first junction impulses which have a slightly longer break period and a correspondingly shorter make period. These impulses are received by the A relay at the intermediate exchange where distortion again occurs due to the unequal lags of *this* relay. Similar distortion occurs in the second junction link, which still further increases the break ratio of the impulses. The net result of the two stages of repetition is an impulse of very short make period and of correspondingly long break period to the relays and magnets of the selector at the terminating exchange.

If the operate lag of each A relay is slightly greater than its release lag, then the opposite effect is produced, i.e. the impulse, as received at the selector, will have a short break period and an abnormally long make period. In some cases the distortion produced in the first junction may be substantially neutralized by an opposite form of distortion in the second junction link.

The worst condition occurs when a number of high resistance junctions are connected together in tandem. If we assume that the impulse frequency can vary between 7 and 12 I.P.S., and that the impulses generated by a subscriber's dial can have a break ratio ranging from 63 to 72 per cent, it is clear that, under the worst conditions, the shortest make period from the dial is of the order of 24 msec (i.e. 28 per cent make at 12 I.P.S.). The slugged type of selector B relay requires (at 12 I.P.S.) approximately 17 msec energization. The total permissible distortion over the whole network is therefore $24 - 17 = 7$ msec. If there are two links in tandem (i.e. three A relays), then B relay failures are likely to occur if the make period is shortened by more than about 2 msec at each A relay. It is clear that "reduced make" distortion is an extremely limiting factor. The right-hand portion of Fig. 212 shows the effect of

excessive distortion of this type. (Note the short period of energization of the B relay and the short interval between pulses of current to the magnet at the terminating exchange.)

Reduced break distortion is not nearly so critical. The shortest break period from a dial at 12 I.P.S. with a 63 per cent break is 51 msec. The pre-2000 type selector magnet requires some 33 msec energization for satisfactory performance (the C relay is slightly better). This permits of a total reduction in the break period of $51 - 33 = 18$ msec —a margin far less critical than the limiting factor on the B relay.

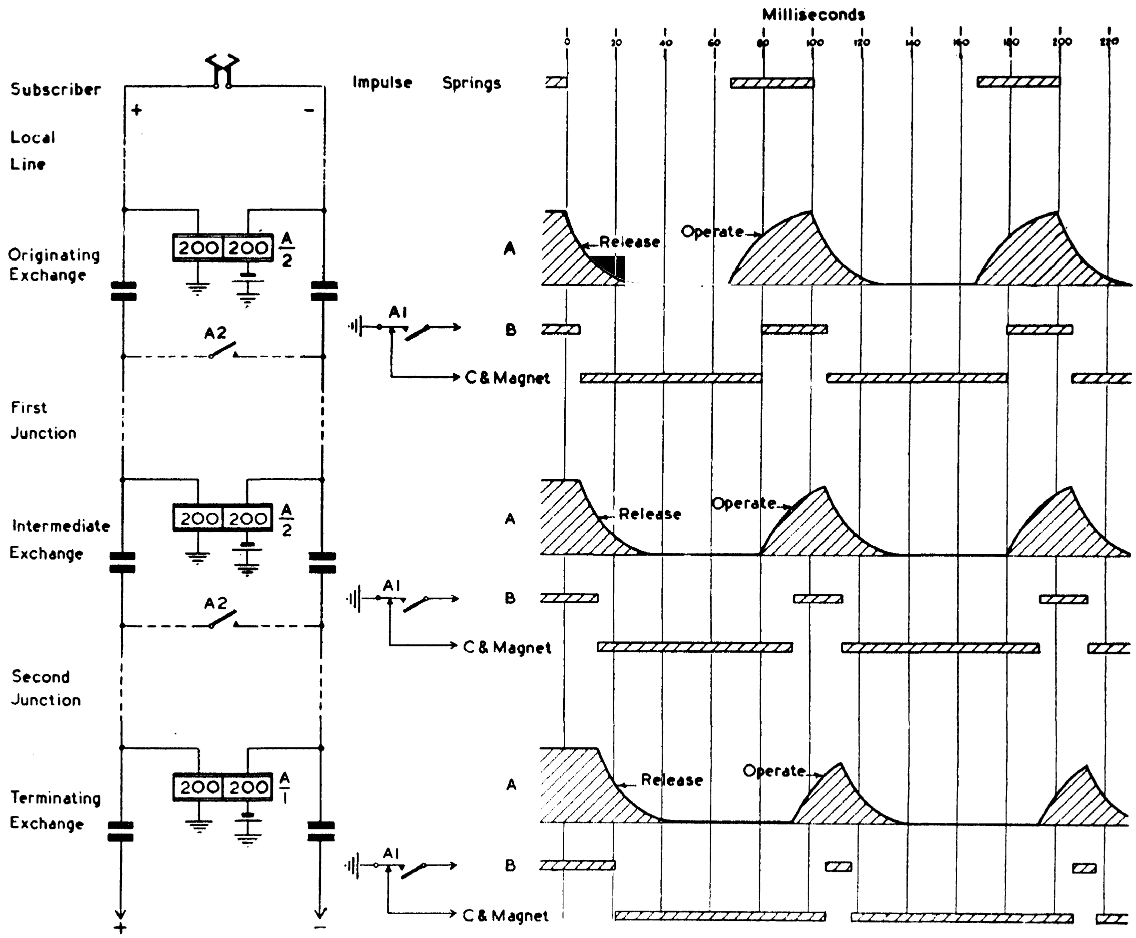


FIG. 212. IMPULSE DISTORTION DUE TO CONSECUTIVE REPETITION

Capacitor Type Impulse Repetition Bridge. Fig. 213 shows the basic circuit of a common form of impulse repetition bridge where the transmission path is maintained by the provision of 2 μF capacitors. When the circuit is seized, relay A is operated and at **A1** energizes B. **B1** in turn prepares the circuit for relay C as in the normal impulsing circuit. At the same time, the operation of **A2** provides a loop through relays D and I to the outgoing junction. This loop seizes the selector at the distant exchange in preparation for impulsing. The purpose of the D and I relays is described later but, briefly, they are required after a call has been established to receive supervisory signals from the distant exchange. It is clear that, since the D and I relays are connected across the speaking pair, either one or both of these relays must be of high impedance to minimize the transmission loss of the circuit.

It is clearly not possible to impulse over a circuit which contains the D and I relays and the distant A relay in series. (The inductance and resistance of this combination would produce a very slow growth of current on closure of the circuit, and hence a very considerable degree of distortion.)

The D and I relays have no function during impulsing, and hence it is possible to arrange the circuit so that these relays are cut out of the impulsing loop during dialling. The condition is met by the provision of an impulse train cover signal obtained by the use of a C relay contact as already described in Chapter V.

At the first release of relay A, contact $A2$ breaks the loop to the distant exchange, whilst at the same time relay C operates via $A1$ and **$B1$**. The operation of **$C1$** during the first break impulse short-circuits the D and I relays to provide a low impedance loop for all subsequent impulses. At the end of the impulse train, C releases and at $C1$ removes the short circuit from the D and I relays so that they can respond to supervisory signals returned over the junction.

Effect of Bridge Capacitors. During impulsing, the − and + lines of the outgoing side of the bridge are connected together through the $C1$ contact (Fig. 214). When the **C1** contact operates, the two 2 μF line capacitors are connected in series across the impulsing relay of the bridge (the resultant capacitance across the A relay is 1 μF). When the dial contacts are open, there is a difference of potential of 50 V between points X and Y, but when the impulse springs close this difference of potential is reduced, the exact value depending upon the line resistance. The bridge capacitors therefore start to discharge at the commencement of a make period, and in so doing delay the change of potential at points X and Y. The operate lag

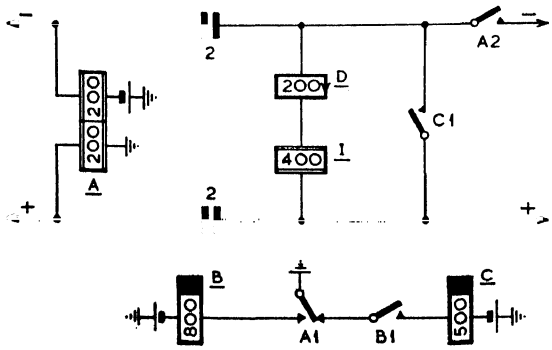


FIG. 213. CAPACITOR TYPE IMPULSE REPETITION BRIDGE

of the A relay is thereby increased, and so is the break period of each impulse.

When the impulsing contacts reopen at the end of the make period, the bridge capacitors charge to the potential of the battery behind the impulsing relay. This delays the release of the relay and tends to *decrease* the break period. Thus the two effects tend to neutralize, the degree of distortion in any particular case being largely dependent upon the value of the line resistance in relation to that of the impulsing relay coils.

The lower portion of Fig. 214 shows the general effect of the bridge capacitors on impulse distortion

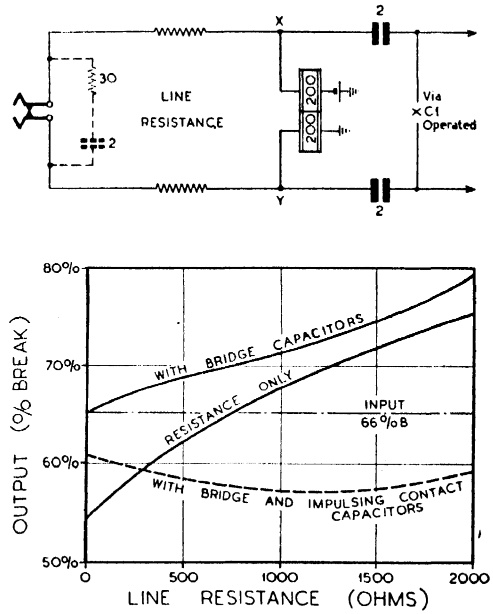


FIG. 214. EFFECT OF BRIDGE CAPACITORS

as the line resistance is increased. The bridge capacitors introduce a general increase in the break ratio, but the increase of break with resistance is not so rapid as when the bridge capacitors are not present. The broken line shows the additional effect of the dial spark quench capacitor. Usually this capacitor is of 2 μF capacitance, so that the total capacitance across the impulsing relay is now 3 μF. Under these conditions the break period tends to decrease slightly as the line is increased up to about 1000 Ω, but beyond this there is a slight increase.

First Impulse Distortion. We have seen in Chapter V (Fig. 194) how the inductance of the impulse accepting relay tends to produce a shortening of the first break impulse. The presence of the D and I relays in an impulse repetition bridge introduces two additional factors which tend to modify distortion of the first impulse. Diagram A of Fig. 215 shows the conditions at the start of the first impulse, whilst diagram B shows the connexions at the commencement of each subsequent impulse.

Just prior to the first release of the $A1$ contact (exchange W), the D and I relays are in series with the two line capacitors across the impulsing relay.

Before the first break the bridge capacitors have attained a steady potential, but when the dial impulse contacts open, the current in the impulsing relay decays at a relatively slow rate in the form of a highly damped oscillation (diagram C) so that the release lag (P) is fairly long. On subsequent impulses the highly inductive D and I relays are short-circuited by the $C1$ contact, so that the shunt across the A relay consists only of the two capacitors in series. The decay waveform is now considerably less damped (diagram E) and there is a more rapid decay of current in the relay, which results in a shorter release lag (Q). The net result is a shortening of the break period on the first impulse as compared with the break period on subsequent impulses.

The current in the distant exchange (X) impulsing relay is less before the first impulse than during the make period between succeeding impulses due to the presence of the D and I relays prior to the first break period. The conditions are shown in diagrams D and F. The smaller current before the first impulse produces a shorter release lag (S) of the distant exchange A relay on the first impulse, thereby lengthening the break period of this impulse. This distortion tends to offset the first impulse distortion due to the conditions across the impulsing relay at the repeating point, but generally there is a shortening of the first break period (i.e. the effect shown in diagram C predominates, and there is reduced break distortion).

The spark quench capacitor across the dial impulsing contacts somewhat modifies the first impulse distortion due to the increased oscillatory tendency of the circuit resulting from the additional capacitance. This tends to shorten the release period (P) at the first break so that the break period of this impulse is more nearly equal to that of subsequent impulses.

Initial Pick-up. The initial seizure or "pick-up" of the distant selector is effected by the closure of the outgoing loop at the impulse repetition point. This loop circuit contains the D, I and A relays all in series. Two at least of these relays must have a high inductance to meet transmission requirements. A high line resistance, coupled with the very high total inductance of the circuit, causes the current to rise extremely slowly (Fig. 216). This very gradual rise of current produces a slow operation of the distant exchange A relay, and there is a tendency for the make-before-break $A1$ contacts to "bunch" for an appreciable period. The bunching period (T_2) may be sufficiently long to operate the B relay before the magnet circuit is disconnected at the break side of the contact. (Under adverse conditions, the bunching period may be as much as 50 msec.) If the B and C relays have time to operate before the disconnexion of the magnet circuit, a false impulse may be given to the selector. The problem is further complicated by bounce at the $A1$ contacts due to the interaction of the tractive force and changing armature load at this point (see Vol. I).

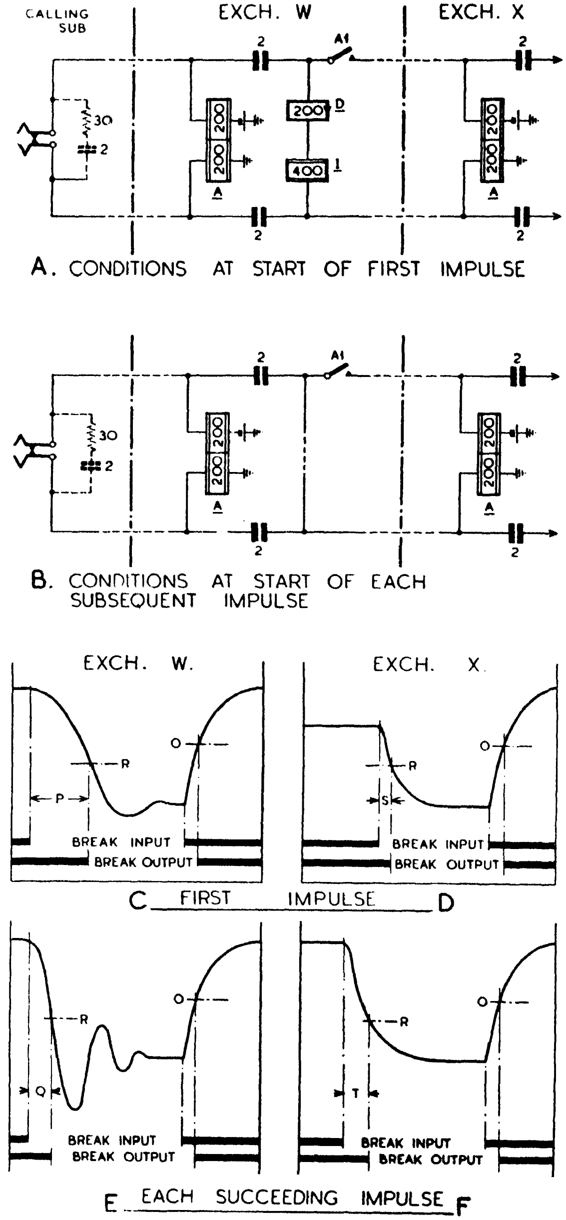


FIG. 215. FIRST IMPULSE DISTORTION DUE TO D AND I RELAYS

The most adverse conditions occur at low exchange volts when the line resistance is high, and when the B and C relays and the magnet are in light adjustment. This initial pick-up condition, rather than actual impulse distortion, may in some cases determine the dialling limits of a circuit.

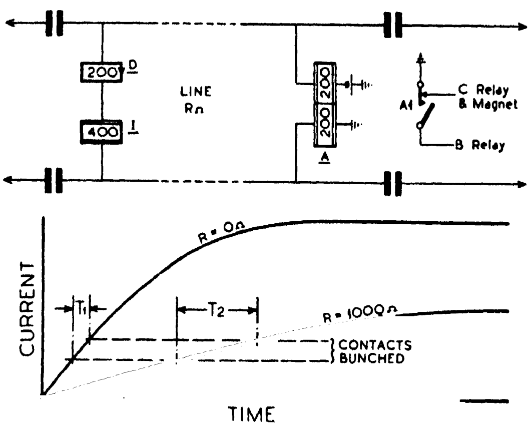


FIG. 216. BUNCHING OF A RELAY CONTACT SPRINGS DURING INITIAL PICK-UP

It is interesting to note that initial pick-up difficulties do not occur when a junction is provided with an impulsing circuit of the "short-circuited B relay" type illustrated in Fig. 189. The A and B relay contacts of this circuit element are arranged so that it is impossible to operate the B relay before the magnet circuit is broken at the break portion of the impulsing contact.

The D relay in an impulse repeating circuit is provided to detect a reversal of line current which occurs when the called subscriber replies (see Chapter IX). The initial pick-up can be materially improved by providing a metal rectifier (MR) across the D relay in such a way that the relay coil is substantially short-circuited for loop currents in the normal pre-answer condition (Fig. 217). This rectifier offers a high resistance when the polarity of the line is reversed on receipt of the answering condition, and substantially the whole of the reversed loop current now passes through the coil of the D relay in the operating direction. The elimination of the inductance and resistance of the D relay steepens the current rise during the initial pick-up, and this in turn reduces the bunching time of the $A1$ contacts.

Subsequent Pick-up. The impulse repetition bridge so far described can also produce difficulties at the *end* of the impulse train, i.e. when the D and I relays are re-introduced into the forward loop by the release of the C relay contact. Immediately after the last impulse of a train, the distant exchange A relay is held over a circuit which consists of the A relay and the line resistance in series to the exchange battery. The holding current at this time is steady, and is determined by the total ohmic resistance of this circuit. After a short period of lag, the C relay releases and the $C1$ contact (Fig. 213) removes the short circuit from the D and I relays. At this time these two relays are completely unfluxed, and at the instant they are introduced into the holding circuit they offer a very high impedance to the loop current. The holding current of the distant exchange A relay therefore drops momentarily, and if the release is of sufficiently long duration there is a danger of a false impulse being transmitted to some subsequent selector.

The sudden introduction of the D and I relays also produces a surge in the line capacitors at the impulse repetition point, which tends to increase the danger of false impulses by lengthening the current interruption to the A relay. Where there are several impulse repetition points in tandem, the distant A relay may receive several flicks before it finally settles down at the end of an impulse train. The most onerous conditions occur when the ohmic resistance of the junctions is high—under these conditions the A relay current may be only slightly above the relçase value.

The danger of false impulses due to the above causes can be materially reduced by the fitting of rectifiers to the D relay as already described (Fig. 217). The difficulty is, nevertheless, very troublesome on calls over two junctions in tandem, and particularly where ballast resistors are used in the

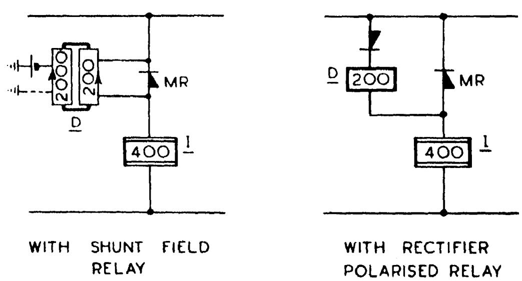


FIG. 217. USE OF RECTIFIERS TO MINIMIZE INITIAL PICK-UP DIFFICULTIES

impulse accepting relay circuit at the impulse repetition points. The impulsing relay used in conjunction with a ballast resistor is usually of $50 + 50\ \Omega$ compared with the $200 + 200\ \Omega$ coil of the non-ballast relay. The different electrical characteristics of the ballast relay make it more responsive to surges at the end of an impulse train, and false impulses may occur even on lines of medium ohmic resistance.

Two-stage Drop-back. Fig. 218 shows a refinement designed to eliminate subsequent pick-up difficulties. This element is used on all impulse repeating circuits which employ a ballast type impulse accepting relay. The circuit provides for the changeover from the impulsing loop to the *D* and *I* loop holding conditions in two successive stages. An additional slow-to-release relay (*CA*) is provided and is controlled by a contact of the *C* relay. At the end of the impulse train, relay *C* releases, and at *C*1 transfers the holding circuit of the distant exchange *A* relay to the path provided by the 800 Ω resistor and contact ***CA*1**. There is some reduction in the holding current at this stage, but the values are adjusted so that there is no danger of false release. The current now commences to build up in the *D* and *I* relays, and, by the time relay *CA* releases to disconnect the 800 Ω resistance at *CA*1, the inductive effects of the *D* and *I* relays are largely overcome. By this means it is possible to maintain the holding current in the distant exchange *A* relay at a safe value during the transition stage. During the changeover period, the changes of potential on the line capacitors are also less violent than in the previous circuit, so that surges are far less troublesome.

Called Subscriber Answer Pick-up. There is one further pick-up problem which introduces a limitation on the junction lengths over which dialling can be permitted. It has already been stated that,

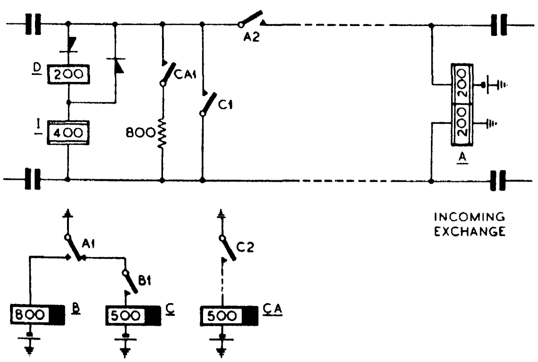


FIG. 218. TWO-STAGE DROP-BACK TO PREVENT FALSE IMPULSE ON SUBSEQUENT PICK-UP

when the called subscriber answers, the line current is reversed at the incoming exchange in order to operate relay *D* at the impulse repetition point. In some circuits this reversal takes place on the line side of the *A* relay, but in other circumstances the reversing contacts are placed in the battery and earth supply to the relay as shown in Fig. 219. In such cases the current in the relay coils is reversed in direction. Under long line conditions, the *A* relay may have just sufficient flux to operate with a reasonable margin of safety under the pre-answer conditions. When the current in its windings is reversed, the flux must fall to zero and then build up again in the opposite direction. Residual magnetism in the core of the

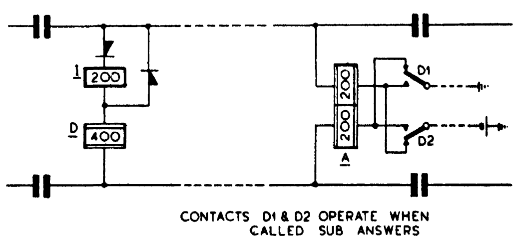


FIG. 219. CALLED SUBSCRIBER ANSWER PICK-UP CONDITIONS

relay may not now allow the flux in the reverse direction to build up to the previous value, so that the relay fails to re-operate.

It is important to consider this effect when deciding upon the limits permitted by initial pick-up and subsequent pick-up considerations. Apart from the effect of residual magnetism, the provision of a rectifier across the *D* relay (Fig. 217) reduces the value of the current after reversal due to the inclusion of the *D* relay resistance in the holding circuit. This factor must also be taken into consideration.

Surges. Some mention has been made of the effects of surges through the line capacitors at an impulse repetition point. During impulsing the capacitors are subject to violent changes of potential due to the varying circuit conditions on both sides of the bridge, and also due to the inductive effects of the relay coils. With each change of potential the capacitors charge or discharge, and some of the resulting currents traverse the coils of the impulsing relay. If such surges occur when the relay is about to operate or release, they may have a very material effect on the impulsing performance of the circuit.

We have seen that, when the dial contacts open at the first break impulse, there is often an oscillatory surge of current in the impulse accepting relay due to the presence of the spark quench capacitor. The resultant varying p.d.s at the relay coils are also applied to the line capacitors, which in turn produce further surges in the impulsing relay. When the impulse accepting relay releases, the *A* relay contact in the forward impulsing loop interrupts the current through the *D* and *I* relays and thereby changes the potential on the forward side of the line capacitors. Moreover, this disconnexion of the current in the *D* and *I* relays

produces an inductive e.m.f. which is often dissipated in the form of an oscillatory current through the capacitors. Before these current surges have died down, the circuit conditions on the forward side of the bridge are again changed by the operation of the C contact (which loops the $-$ and $+$ lines) thereby producing more current surges. A further series of surges occurs when the dial contacts remake at the end of the impulse.

It is clear that the electrical characteristics of the line on both sides of the impulse repetition bridge have a material effect upon the nature and magnitude of the surge currents. Also, where there are several impulse repetition points in tandem

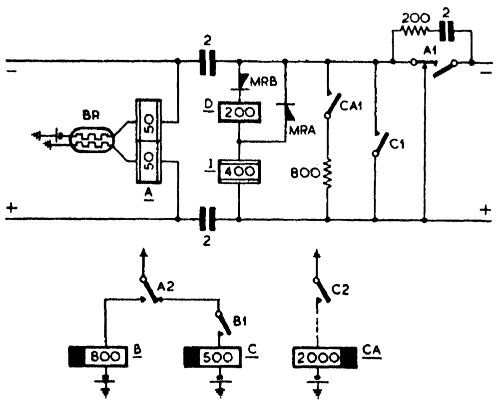


FIG. 220. USE OF MAKE-BEFORE-BREAK "*A*" CONTACTS TO PREVENT SURGE RE-OPERATION OF *A* RELAY AT FIRST IMPULSE

any capacitor surges in one bridge are propagated over the line to other impulse bridges. The whole effect is very complex, especially in view of the fact that the surges at the several bridges do not occur concurrently, but are subject to a time delay due to the consecutive operation of the relays at successive points.

All current surges in a telephone line can be broadly classified into one or other of the following categories:

Longitudinal surges which travel along both wires of a circuit in the same direction, and ultimately return via suitable earth connexions (i.e. at any instant the currents in the two wires are in the same direction).

Transverse surges which circulate round the loop formed by the speaking pair (i.e. at any instant the currents in the two wires are opposite in direction).

In the capacitor type of bridge, longitudinal surges can pass readily through the line capacitors at each point of repetition and pursue various paths through the impulsing relays. This is a fundamental defect of the capacitor type of bridge resulting from the nature of the coupling between the input and output sides of the circuit. The longitudinal surges are often sufficiently large to cause serious modification of the wave shape on one link due to the surges on the remaining links of the connexion. Should these modifications of wave shape occur when the impulsing relay is about to operate or release, impulsing is affected. Since it is impossible to prevent the transmission of longitudinal surges from one side of the bridge to the other, the best that can be done is to minimize the amplitude of such surges.

At the commencement of an impulse train, *transverse* surges are also propagated from one side of the bridge to the other, but the closure of the $C1$ contact (shortly after the beginning of the first break impulse) provides an effective shunt for all subsequent surges of this type (Fig. 213). The effect of these surges is thus limited to the first break, and to the relay in the link following that on which the surge occurs. Nevertheless the transverse surge at the commencement of the first impulse is often large enough to have an appreciable effect, especially with impulse relays of the ballast type which are generally more sensitive on release.

Under adverse conditions it is possible for the impulsing relay to re-operate during the first break due to the surge currents through the D and I relays and the line capacitors. The effect can be reduced by replacing the normal make type of A relay contact on the forward side of the bridge by a contact of the changeover or make-before-break type (Fig. 220). The break side of the $A1$ contact now places a short circuit across the D and I loop *before* relay C operates at the first break. The circuit arrangement partially simulates the conditions on subsequent breaks where the D and I loop is short-circuited by the $C1$ contact. This circuit device cannot, of course, affect the conditions prior to the first release of the A relay and does not therefore prevent the first impulse distortion described in previous paragraphs.

Fig. 220 shows a quench circuit consisting of a capacitor and resistor in series across the $A1$ contact. In some cases this quench circuit improves the impulsing performance of the circuit, but in other cases (particularly on long amplified lines with a high wire-to-wire capacitance) the presence of the spark quench capacitor may actually degrade the impulsing limits. The quench circuit is therefore not provided in all cases.

Although Fig. 220 incorporates the various refinements considered in previous paragraphs and

represents the current practice in capacitor type repetition bridge design, it suffers from certain fundamental disabilities. Possibly the greatest objection to the use of capacitor type bridges is that the performance of any circuit which includes such bridges is very difficult to estimate in advance, owing to the indeterminable effects of the capacitor surges. The capacitor surges also tend to produce loud clicks at the end of each impulse train, which in some circumstances may become of serious magnitude. The first impulse distortion may be appreciable, and it is difficult to obtain a good signal shape with an impulsing relay which must be of high impedance to meet transmission requirements. Similarly, the necessity for high impedance relays on the forward side of the bridge tends to aggravate pick-up troubles.

Transformer Type Impulse Bridge. From the point of view of speech transmission, transformer coupling can be used at an impulse repetition point instead of the capacitor coupling so far considered. The introduction of a transformer bridge (Fig. 221) has distinct advantages from an impulsing point of view. The impulse accepting relay can now be of the high speed type with a low impedance and low eddy current losses. It is true that this relay works in series with the windings (W and X) of the bridge transformer, but, by suitable transformer design and by correctly loading the secondary circuit, the effect of the windings can be reduced to small proportions. The only change in the impulsing circuit during a train of impulses is in the load on the secondary windings (Y and Z), and the bridge can be designed so that there is a negligible difference in the effect on the impulsing relay between the first and subsequent impulses. The high speed properties of the relay allow full advantage to be taken of the improved impulsing waveform, and minimize the amount of distortion produced throughout a wide range of line conditions.

The use of transformer coupling also eliminates to a large extent the transmission of longitudinal surges from one link to another. Equal longitudinal currents on the line connected to the left-hand side of the bridge neutralize in the transformer windings (W and X), and there is no induced e.m.f. in the right-hand windings (Y and Z) of the transformer. If the longitudinal surges are unbalanced, a transverse e.m.f. of magnitude depending upon the degree of unbalance will, of course, be induced in the right-hand windings of the transformer. By the use of a high speed impulsing relay, any such transverse surges are suppressed by the release of contacts $A2$ within a millisecond or so of the commencement of the first break impulse. There is therefore only a very short period during which transverse surges can be transmitted from one link to the next. This feature, in conjunction with the virtual elimination of longitudinal surges, makes the impulsing performance of any one relay in the chain substantially independent of the conditions on the remaining links of the circuit.

Such independence can be obtained only if the surge interaction across the bridge is reduced to sufficiently small proportions. For example, there will be a surge in windings Y and Z when contact $A2$ releases at the first impulse. The nature and magnitude of this surge current depends upon the

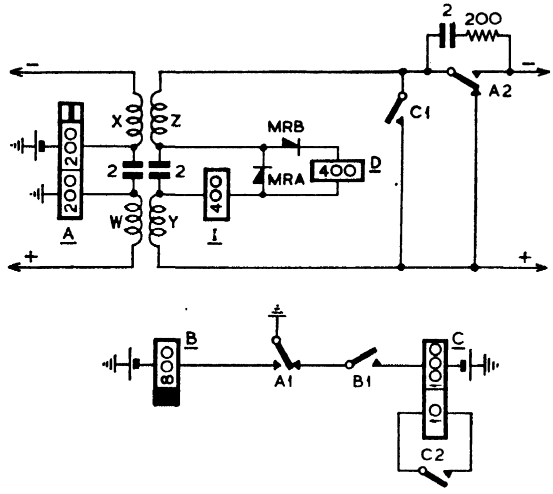


Fig. 221. Transformer Type Impulse Repetition Bridge

characteristics of the bridge transformer. If the constants are such that heavy oscillatory currents are produced, these surges may be reflected into the primary windings and may interfere with the waveform of the incoming impulses to produce distortion. It is possible to design the complete bridge as a "high-pass" filter (see Chap. IX) so that there is a minimum attenuation over the speech-frequency range but a very high degree of attenuation at the lower impulsing frequency (and its more important harmonics). By this means, a bridge can be produced which is satisfactory from a speech transmission aspect, and which gives negligible surge interaction over a wide range of secondary impedance from short circuit upwards.

The upper part of Fig. 222 is a reproduction of an oscillogram showing the current in the impulsing relay of a capacitor type bridge. The very violent surge currents at the commencement of the first impulse are clearly indicated, as also are the less

violent, but still appreciable, surges at the commencement and end of each subsequent impulse. The lower part of Fig. 222 shows the current in the impulsing relay of a transformer type bridge under the same impulsing conditions. The almost complete absence of surges, and the greatly improved waveform will be noted.

The use of transformer coupling also permits the use of low impedance supervisory relays (*D* and *I*) on the outgoing side of the circuit. A reduction in the impedance of the *I* relay very materially improves the performance of the circuit under initial and subsequent pick-up conditions. In Fig. 221 the *D* and *I* relays are connected in series, but rectifier *MRA* effectively short-circuits the *D* relay under pre-answer conditions. The initial seizure loop consists mainly of the *Y* and *Z* windings of the transformer and the low impedance

FIG. 222. IMPULSE WAVEFORMS WITH CAPACITOR AND TRANSFORMER TYPE BRIDGES

I relay in series. There is therefore a comparatively quick build-up of current, especially if the distant impulse accepting relay is of the low impedance, high speed type. Subsequent pick-up trouble is similarly reduced due to the more rapid build-up of current when the *C* contact releases at the end of an impulse train, but in certain circumstances it may still be necessary to retain the two-stage drop-back feature already described in connexion with Fig. 218.

If desired the *D* and *I* relays could be connected in parallel instead of in series as shown in Fig. 221. There is very little advantage to be gained from this arrangement under pre-answer conditions since, in the series arrangement, the *D* relay is effectively eliminated from the holding loop at this time by the shunting effect of rectifier *MRA*. When the called subscriber answers, however, the parallel arrangement produces a slightly greater current in the holding loop after the reversal of the line current, and so somewhat improves the called-subscriber-answer pick-up limits.

An alternative arrangement would be to place the *D* and *I* relays in parallel, with the *D* relay so polarized that it operates immediately on seizure and releases when the called subscriber answers. This would give a very low impedance holding loop, which would still further improve the initial and subsequent pick-up performance of the circuit. The release of the *D* relay would then become the metering and supervisory signal. It is usually not good practice to have such an important signal dependent upon the *release* of a relay due to possible mis-operation resulting from fortuitous release (which can occur much more readily than fortuitous operation).

The transformer type bridge with high speed impulsing relay has two inherent limitations. On very short amplified lines, the 2 μF capacitor across the impulsing relay, together with the 1 μF capacitor in the 4- to 2-wire termination, tend to give rise to impulse splitting. The difficulty does not occur on longer lines, and is probably of little practical significance. Also the high speed relay is very responsive to line surges, and difficulties may occur when a transformer type bridge is used at one repetition point in a chain of connexions which includes impulse bridges of the capacitor type. Nevertheless the principles employed in the transformer type bridge are a real improvement over those of the capacitor type bridge. Undoubtedly the greatest merit of the transformer type bridge is the prevention of surges between successive links, which in turn enables the impulsing performance of a chain of connexions to be more easily determined.

Impulse Correction. Apart from the "pick-up" difficulties already discussed, impulse distortion determines the maximum length of line, or, what is more important, the number of links in tandem, over which dialling can be employed. It follows that, if a means can be provided for correcting the inevitable distortion due to the line, then the dialling range (or *dialling limits*) can be increased. One of the more obvious methods of impulse correction is the provision of an electrical network (usually composed of capacitors and resistors) which, when connected to the impulse accepting relay, produces an artificial distortion equal and opposite to the distortion introduced by the line. The great disability of this method is the necessity for individual adjustment of the correcting network on each particular line. Moreover, whereas in some cases it is possible to anticipate the degree of distortion of the received impulses, there are many circumstances where the impulses received at a given point have widely different values of distortion depending upon the routing of the call. For example, the calls received on an incoming junction at one exchange may have originated at an adjacent exchange or, alternatively, may be

from a more distant exchange with several intervening stages of impulse repetition. It is clear that the degree of impulse distortion may be vastly different even on consecutive calls over the same junction.

Most modern impulse correction devices consist of a timing element which modifies the received impulses to give an output where the break and/or make periods are of fixed or minimum duration. The ideal arrangement would be a circuit which would give an output with a break-to-make ratio of 2 : 1, irrespective of the impulse frequency and for a wide range of incoming ratio. This ideal is difficult to achieve in practice without the introduction of impulse storage facilities, for, in order to determine the correct length of break, it is necessary first to measure the length of a complete impulse period (to decide the impulse frequency) and then to apply the appropriate break period to give the required ratio. Owing to the complexity of fixed-ratio correctors they have not, so far, been used to any great extent. There is, however, a number of comparatively simple schemes by means of which impulse distortion can to some extent be reduced. Most of these schemes are designed to give an output with a fixed break or make period or, alternatively, break and make periods of predetermined minimum values.

Fixed-break Output Correctors. Fig. 223 shows the fundamentals of a fixed-break output corrector which is used to some extent in America. Relay *A* operates when the circuit is seized and ***A*1** energizes *B*. At the commencement of the first break impulse, *A*1 releases and energizes relay *D* via ***B*2** and *E*1. The operation of ***D*1** starts the output break period whilst ***D*3** completes a circuit for relay *E*. ***E*1** now disconnects the initial operating circuit of *D* but a temporary holding circuit is provided by ***D*2** which allows a current to flow through relay *D* to charge capacitor *QA*.

The rate of charge is controlled by resistor *R* and the remaining constants of the circuit. As the charge on the capacitor increases, the current through *D* gradually falls until, after a predetermined time, the flux falls to the release value of the relay. Thus the duration of the output break period is always equal to the operate lag of *E* plus the timing of the capacitor charge circuit—irrespective of the character of the incoming impulse. When *D* finally releases, *QA* discharges to the earth at *D*2 and the output loop is re-established at *D*1. The cycle of operations should be clear from the chart in the lower part of Fig. 223.

A careful analysis of the conditions will show that the circuit will work with any ratio of input and with any impulse frequency provided that:

(*a*) the input break period is greater than the operate lag of *D*; and

(*b*) the total impulse period (make + break) is not less than the fixed output break period plus the time necessary to discharge capacitor *QA* after the release of *D*2.

The greatest disability of any fixed-break (or fixed-make) corrector circuit is the distortion of *ratio*

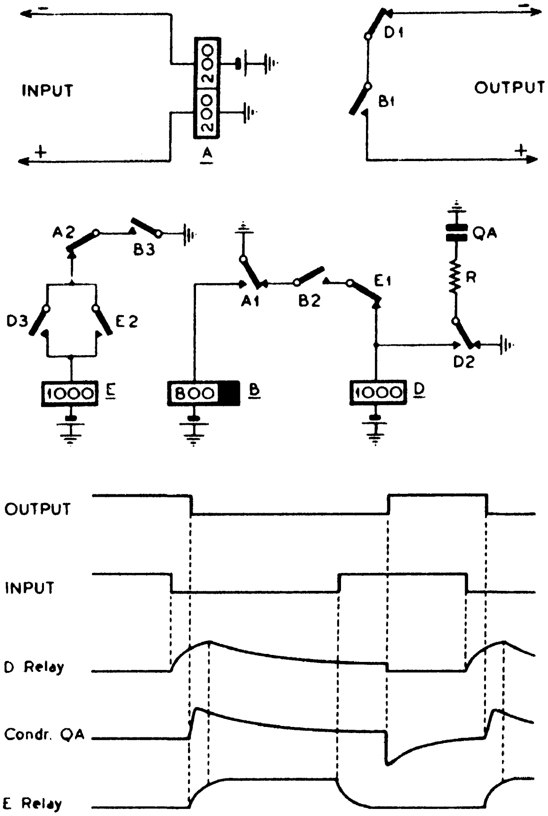


FIG. 223. IMPULSE CORRECTOR CIRCUIT WITH FIXED OUTPUT BREAK PERIOD

which occurs at all impulse frequencies except that for which the circuit is designed. For instance, if, in the circuit of Fig. 223, the fixed-break period is adjusted to 65 msec, the output ratio is 65 per cent break when the impulse frequency is 10 I.P.S. If, however, the incoming impulses have a frequency of, say, 7 I.P.S., then the output ratio is 65 ÷ 1000/7, i.e. 45 per cent break. Hence, if the incoming impulse frequency differs appreciably from the nominal frequency, the output from the

"corrector" may be considerably more distorted than the original incoming impulses!

This limitation of the fixed-break corrector is clearly shown if, as in Fig. 224, the output ratio

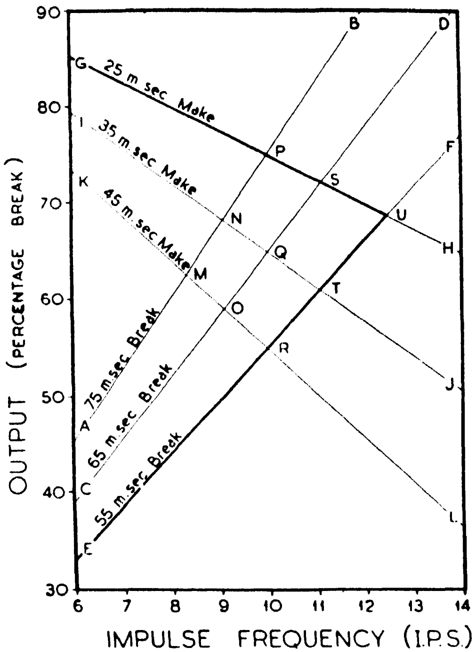


FIG. 224. LIMITING CONDITIONS OF FIXED PERIOD CORRECTOR CIRCUITS

for various fixed-break periods is plotted against the impulse frequency. With the normal dial limits of from 9 to 11 I.P.S. and with a fixed-break period of 65 msec (line *CD*) the output break ratio can vary from 58 per cent to 71 per cent. Fig. 224 also shows the similar effects when a circuit is designed to give a fixed-make output period. With such a circuit the output ratio *decreases* with increase of impulse frequency as compared with the opposite characteristic of fixed-break circuits. It is interesting to note that, at normal impulse frequencies and ratios, there is less change of output ratio than with a fixed-break circuit under comparable conditions.

Minimum-break, Minimum-make Correctors. As an alternative to the fixed-break or fixed-make impulse corrector, it is possible to have a circuit which will ensure predetermined *minimum* break and make periods. This method is favoured by German circuit designers and its principle is illustrated in Fig. 225. Prior to impulsing, relays *A*, *H* and *F* are operated. On the first release of *A*, *A*1 releases *H* and *H*1 disconnects the output loop. At the same time *H*3 breaks the holding circuit for *F* and operates *E*. *F* is a slugged relay with a release lag equal to the minimum break period required. Its contact ***F*1** prevents the re-operation of *H* until the minimum break period has elapsed and then only if ***A*1** (the contact of the impulse accepting relay) has re-operated. The length of the output break period is therefore determined by the release lag of *F* or the length of the received break period, whichever is the longer.

Relay *H* re-operates at the commencement of the make period and at ***H*3** disconnects the *E* relay.

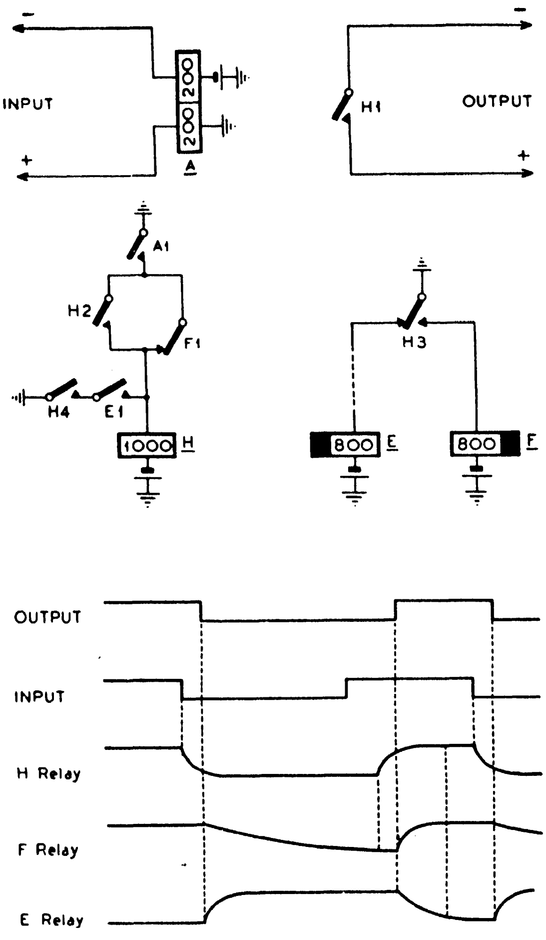


FIG. 225. MINIMUM-BREAK, MINIMUM-MAKE IMPULSE CORRECTOR CIRCUIT

Relay *E* is also slugged to give a release lag of the required minimum make period. Relay *H* is now held via ***H*4** and ***E*1** until *E* releases, irrespective of the time for which the ***A*1** contact is operated. Hence the output make period is either the release lag of *E* or the make period of the incoming

impulse, whichever is the longer. The operating sequence of the various relays, etc., is illustrated at the bottom of Fig. 225.

The important feature of the minimum-break, minimum-make corrector circuit is that complete failure will occur if the total incoming impulse period is less than the fixed minimum output break and make periods together. Under these conditions the output becomes increasingly out of step with the incoming impulses until a point is reached when the $A1$ contact completely loses control. This result is illustrated in Fig. 224. If the fixed break and make periods are, say, 55 msec and 25 msec respectively, then failure occurs at the intersection (U) of the two diagonals EF and GH, i.e. at about 12·5 I.P.S. Similarly, if the break and make periods are 65 msec and 35 msec respectively, failure occurs at a maximum impulse frequency of 10 I.P.S. (point Q).

The output ratio at various frequencies below the failure point is of special interest. For purposes of illustration let it be assumed that the circuit is designed to give minimum break and make periods of 55 and 25 msec respectively. If the break ratio of the received impulses is less than the value for each frequency given by the line EU, the output ratio will be raised to this value. Conversely, if the input break ratio is greater than the value at each frequency given by the line GU, the output ratio is lowered to this value. For example, if the input is 40 per cent break at a frequency of 10 I.P.S., an output of 55 per cent break is obtained. If, on the other hand, the input is, say, 80 per cent break at 12 I.P.S., the impulses are corrected to give an output ratio of 70 per cent break. Where the incoming impulses are of higher ratio than the line EU and of lower ratio than line GU, i.e. if they fall within the angle GUE, they are unaffected by the corrector circuit and are repeated as received.

It can be said that, generally speaking, the minimum-make, minimum-break corrector is less satisfactory than the fixed-break type of circuit at high impulse frequencies due to the above-mentioned failure point. On the other hand, at low impulse frequencies it produces less distortion than the fixed-break type of corrector. The use of slugged relays in Fig. 225 is somewhat of a disadvantage in practice owing to the difficulty of controlling the release lags accurately. This is particularly important since the sum of the release lags controls the failure point of the circuit.

Impulse Regeneration. In all impulse correcting circuits each outgoing impulse is controlled directly by the corresponding incoming impulse, the circuit merely modifying the relative proportion of break-to-make period. Impulse corrective devices cannot possibly correct for impulse frequency. The impulse frequency is not, however, influenced by the line characteristics and cannot be distorted during transmission. Impulse corrective devices are of appreciable value when the impulse frequency can be controlled within fairly close limits at the source. In the Post Office standard system the automatic switching network must (in general) be capable of transmitting impulses generated by the subscriber's dial. The dial cannot, for obvious reasons, be a very precise instrument, and cost considerations prevent the maintenance of dial speeds within very close limits. For these reasons, impulse correction devices have not so far been used to any appreciable extent in this country.

Circuit design practice in the British Isles favours the adoption of impulse *regeneration* in preference

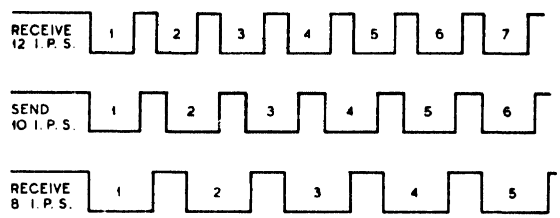


FIG. 226. SHOWING NECESSITY FOR IMPULSE STORAGE WITH IMPULSE REGENERATION

to impulse *correction* when the degree of distortion prevents the direct transmission of the original impulses. Impulse regenerators differ from impulse correction circuits in that their output is not directly controlled impulse-by-impulse by the incoming signals. The incoming impulses are utilized to position a mechanism or to set up other circuit conditions which are then utilized to control outgoing impulse trains from an independent impulse generator which is correct both in respect of speed and ratio.

Any impulse regenerator which is designed to correct impulse frequency must necessarily incorporate an impulse storage system. This can readily be seen from Fig. 226. If the received impulses have a frequency of 12 I.P.S. and the outgoing impulses have the standard frequency of 10 I.P.S., then it is clear that 7 impulses are received during the time taken to send out 6 impulses at the lower frequency. Some system of storing the incoming impulses is therefore necessary. On the other hand, if the received impulses are of lower frequency than the output of the regenerator, then there is a danger that even if storage facilities are provided, the outgoing impulses may catch up with the incoming signals. In Fig. 226, for example,

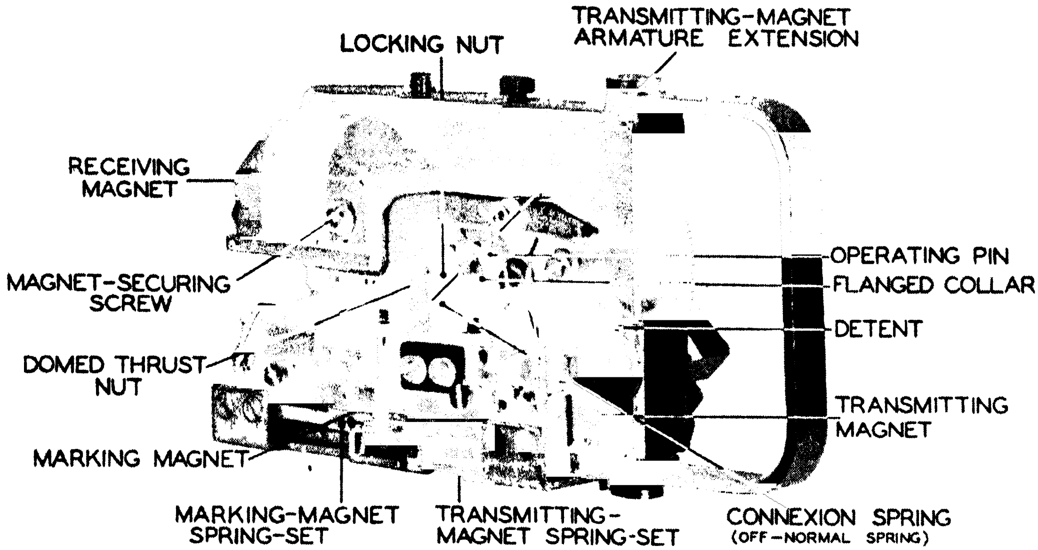


FIG 227. MECHANICAL IMPULSE REGENERATOR RECEIVING SIDE
(Impulse Regenerator No 1)

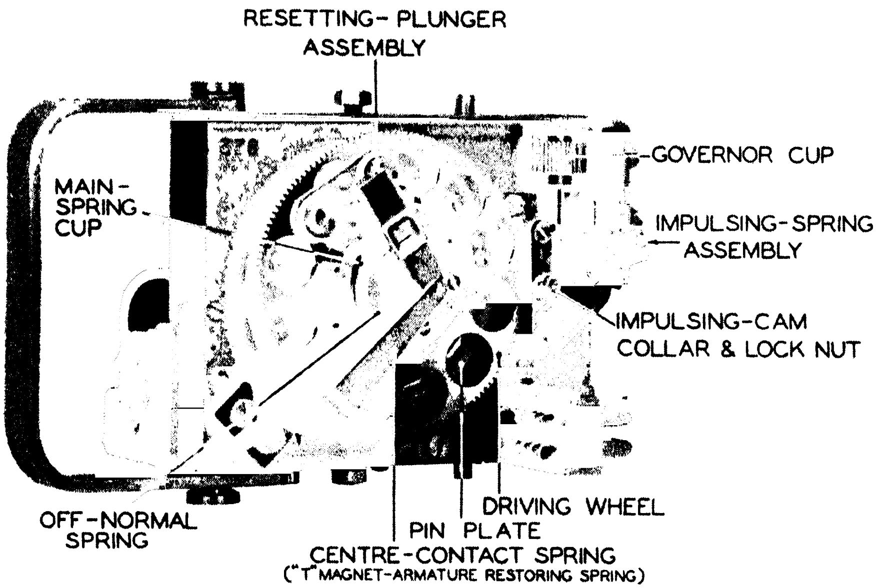


FIG 228. MECHANICAL IMPULSE REGENERATOR—TRANSMITTING SIDE

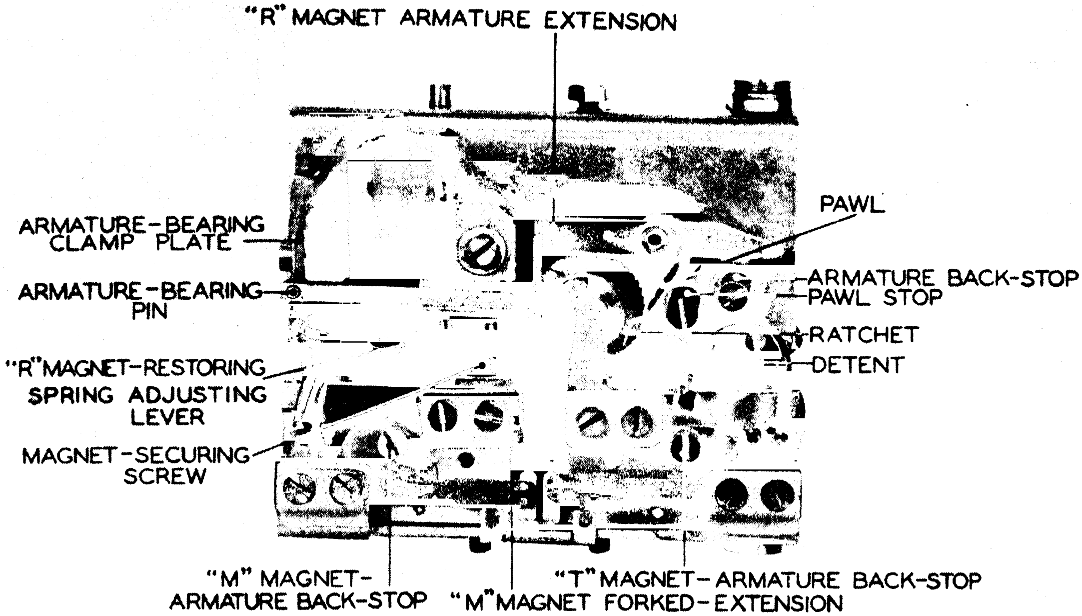


FIG. 229. SIDE VIEW OF REGENERATOR SHOWING DETAILS OF MAGNETS, STORAGE RATCHET, ETC.

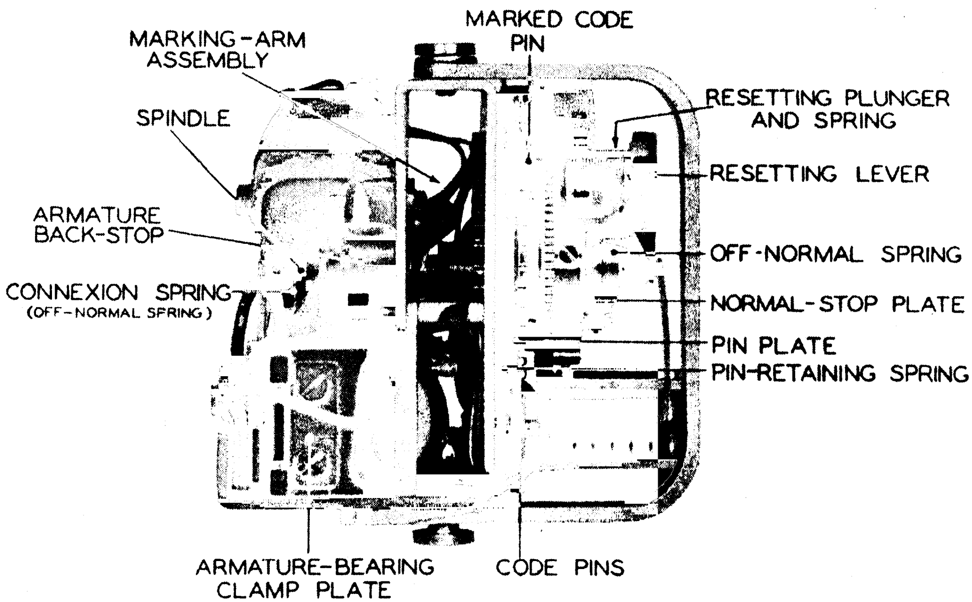


FIG. 230. END VIEW OF REGENERATOR SHOWING MARKING PINS, ETC.

if the incoming impulse trains have a frequency of 8 I.P.S., 6 impulses will be transmitted for the receipt of 5 incoming impulses. For these reasons impulse storage facilities are an essential part of impulse regenerators, and it is usual to delay the transmission of the first impulse train until the whole of the first incoming train has been received.

It has been suggested that there are considerable merits in arranging that in all cases the impulse trains from the subscriber should be directed to a regenerator at his local exchange. The generator could then send out corresponding impulse trains of accurately controlled ratio and frequency to step the switching mechanisms. This method would certainly increase the junction limits over which impulsing is possible without further regeneration and it would, moreover, enable the use of simple and inexpensive correction devices of the type illustrated in Figs. 223 or 225, at subsequent points in order to extend still further the range of dialling. As will be seen later, this form of impulse regeneration is at present obtained in the director system (Chapter XIII).

The great disability of impulse regenerators is the comparatively high cost of the necessary impulse storage system. Generally speaking, mechanical storage devices are less expensive than electrical storage circuits utilizing relays and selectors.

Mechanical Impulse Regenerator. The Post Office standard mechanical impulse regenerator (Impulse Regenerator No. 1) is illustrated in Figs. 227 to 230, whilst Fig. 231 shows the mechanical details and the basic elements of the associated circuit in highly simplified form. The unit is built round a pressing of brass sheet and is designed to fit on the face of a standard relay set mounting plate. The connexions of the regenerator unit are brought out to a 12-point plug which engages with a jack of similar size on the relay set mounting plate. By this arrangement it is possible readily to replace the regenerator or to remove it from its associated circuit for adjustment purposes.

The mechanism may be considered as comprising five main elements:

(*a*) *The receiving element* consists of an electromagnet (*R*) (Fig. 231) which is associated with a storage ratchet wheel (*SR*). The incoming impulses are repeated to the receiving magnet (*R*) which, in turn, steps the ratchet wheel in accordance with the number of impulses received. It will be noted that the receiving mechanism is "reverse-acting," i.e. the storage ratchet is moved during the release of the receiving magnet armature.

(*b*) *The storage element* consists of 42 code pins arranged as a circle around the main shaft of the mechanism. The pins pass through the fixed base-plate of the mechanism and are free to move in an axial direction. It is important, however, that the pins should move only when they are operated by the marking or re-setting mechanisms and that they should retain their position after they have been set. To meet these requirements the pins are held friction-tight by an endless helical coiled spring which exerts transverse pressure on the code pins via small nickel silver rollers. The helical coiled spring applies a sufficient pressure to every pin to prevent movement unless an axial load exceeding some 60 g is applied to the pin. It is found that with this arrangement any overshooting or movement of the pins due to vibration is avoided, whilst the design is such that any wear in the pin guide holes is taken up automatically.

(*c*) *The marking element* consists of a marking lever (*ML*) which rotates with the storage ratchet wheel. Normally the marking lever is just clear of the code pins, but at the end of an impulse train the release of the marking magnet (*M*) allows the marking lever to engage with a particular code pin (*MP*) and to move it so that the pin projects on the sending side of the base-plate.

(*d*) *The impulse sending element* consists of a pair of interrupter contacts controlled by a triangular cam which is geared to the impulse selecting wheel (*ISW*). A governor (substantially of the dial type) is provided on the impulse cam shaft to control the speed of rotation. A coiled spring (*CS*) connected on the one side to the main shaft and on the other to the impulse selecting wheel provides the necessary driving force.

(*e*) *The transmission control element* comprises a pin re-setting plunger (*PRP*) which has at its extremity a tripping arm (*TA*). The pin re-setting plunger and tripping arm are mounted on the impulse selecting wheel and rotate with the latter. When the mechanism is at rest, the tripping arm (*TA*) is held against an exposed marking pin (*MP*) by the coiled spring (*CS*). When it is desired to send out an impulse train, magnet *T* is energized and, by operating through an inner spindle (*IS*) and the re-setting lever (*RL*), depresses the pin re-setting plunger (*PRP*) against the small helical spring. The end of the tripping arm (*TA*) is so shaped that the operation of magnet *T* restores the marking pin (*MP*) to its normal position. On the release of the transmitting magnet (*T*), the tripping arm (*TA*) restores, and the impulse selecting wheel can now rotate under the action of the coiled spring until the tripping arm encounters the next operated marking pin. The whole

mechanism is so geared that the appropriate number of impulses is sent out whilst the tripping arm moves from one marking pin to the next operated pin.

Off-normal contacts (not shown in Fig. 231) are provided and are arranged to operate immediately the first impulse is received, and to release only when all stored impulses have been transmitted. Contacts are also associated with the armatures of the *M* and *T* magnets to provide the necessary switching conditions in the control circuit.

The basic elements of the regenerator circuit are also given in Fig. 231. Relay *A* is, as usual, the impulse accepting relay and is operated when the circuit is first seized. ***A*1** operates *B* and ***B*1** in turn prepares the circuit for the *C* relay and the *R* magnet. At the first break impulse, the release of *A*1 applies earth to the *C* relay and receiving magnet. Contact ***C*1** operates the marking magnet (*M*) to withdraw the marking lever (*ML*) from engagement with the code pins. At the same time ***C*2** energizes relay *IP*. Relay *C* is slow to release so that it remains operated during the receipt of an impulse train.

As each impulse is received, the receiving magnet steps the storage ratchet wheel. At the end of the impulse train relay *C* releases and at *C*1 disconnects the circuit of the marking magnet (*M*). As the armature of this magnet releases, the marking lever operates the code pin opposite the marking lever. If, for example, the initial digit is 7, then the release of the marking magnet at the end of the impulse train causes the operation of the 7th code pin from the starting position.

When the storage ratchet is moved off-normal at the first impulse, the off-normal springs ***(N1)*** operate, and the closure of the marking magnet interrupter contacts (*Mdm*) at the end of the impulse train allows relay *BY* to operate and to lock independent of the marking magnet contacts at ***BY*5**. Contacts ***BY*1** and ***BY*2** change over the normal speech circuit and connect the regenerator impulsing contacts to the outgoing line. ***BY*3** provides an alternative holding circuit for the *IP* relay under the control of contact *MD*1. The *IP* relay is slow to release which covers the period between the release of *C*2 and the operation of ***BY*3**. A circuit is now provided for the *MD* relay through ***BY*4**, the normal contacts of the *T* magnet interrupter springs ***(Tdm)***, and the metallic contact between the tripping arm (*TA*) and the marking pin (*MP*). *MD* operates after a short lag and at ***MD*1** disconnects relay *IP*. After a fairly long release lag the restoration of *IP*1 energizes the transmitting magnet which, by operating the tripping arm (*TA*), restores the marking pin to normal. The operation of the transmitting magnet interrupter springs ***(Tdm)*** disconnects relay *MD*, and a circuit is again formed at *MD*1 for the re-operation of the *IP* relay. ***IP*1** now disconnects the transmitting magnet and so allows the restoration of the tripping arm.

In the meantime the second digit is received by the *R* magnet and causes the storage ratchet wheel to be rotated further. At the end of the second impulse train a further code pin is operated and so on for each impulse train received. On the transmitting side of the mechanism, the restoration of the tripping arm (after the completion of the first impulse train) allows the impulse selecting wheel to continue its rotation until the next marking pin is encountered, when the circuit again operates as described above. It will be noted that the pause between the transmission of successive digits is controlled by the operate lag of relay *MD* plus the release lag of relay *IP*. The interdigit pause can readily be made of any required duration by suitable timing of these relays.

It will be noted from the above that the first outgoing impulse train is deferred until the initial digit is completely received. This delay ensures that, should the incoming impulses be of lower frequency than the regenerated impulses, the transmitting side of the mechanism will not overtake the receiving element. The regenerator will readily handle 16 trains each of 5 impulses with adverse input speeds and interdigit pause times.

The design of the regenerator is such that it is capable of receiving impulses of 30 msec make period and 8 msec break period. The adjustment instructions specify that the governor should be set so that the outgoing impulse frequency is between 9·5 and 10·5 I.P.S. The regenerated impulse ratio is substantially fixed (at between 63 and 70 per cent break) by the design of the three-lobed cam, but minor adjustments can be made by the positioning of the contact springs.

Electrical Impulse Regenerators. There are various methods of obtaining impulse regeneration by purely electrical means. All such electrical regeneration circuits must make provision for:

(*a*) Counting the incoming impulse trains. The counting element may consist of a group of relays or, alternatively, may utilize a group of uniselector switches.

(*b*) Storage of the received impulse trains. Here again, the storage circuit can be of the relay or of the uniselector type. (One proposal provides for digit storage on a multiple-section capacitor.)

(*c*) Generation of the impulses to be transmitted. The impulse source may take the form of an

impulse machine or, alternatively, impulses may be generated by some arrangement of vibrating or interacting relays.

(*d*) The control of the outgoing impulses in accordance with the digits received by the regenerating impulse trains in order to route the call to the required destination in the most economical way.

The various aspects of impulse counting, impulse storage, re-transmission, and so on, are considered in the following paragraphs.

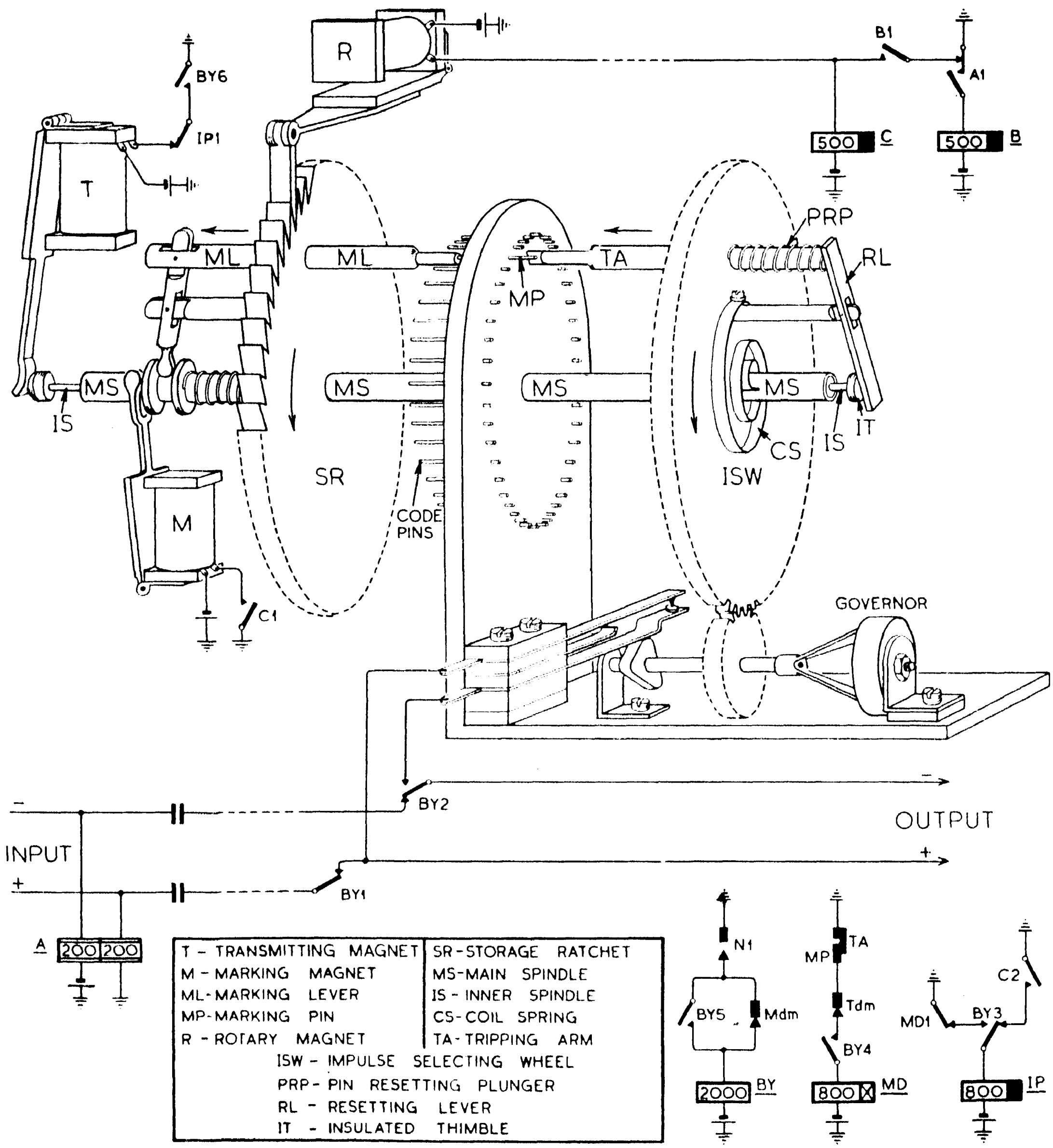


FIG. 231. MECHANICAL ARRANGEMENTS OF REGENERATOR—DIAGRAMMATIC

ation circuit. The usual requirement is for the re-transmission of the same digits as are received, but this is not necessarily so in every case. In some circumstances it may be necessary to translate the incoming digits into separate and distinct out-

Impulse Counting by Uniselectors. Probably one of the simplest methods of counting the number of impulses in a train is to utilize a uniselector mechanism which can be made to move one step on receipt of each break impulse. The circuit

arrangements are very straightforward and are illustrated in Fig. 232. Contact $A1$ is the contact of the impulse accepting relay, and it is so connected that each time $A1$ is released a pulse of current is directed to the uniselector magnet. When (as is usual) a reverse-acting mechanism is used, the wipers make one step at the end of each break impulse. At the termination of the impulse train, relay C (not shown) is released and $C1$ applies an earth to the marking wiper of the uniselector. Depending upon the contact to which the wipers have been stepped, this earth is connected to one of the marking points 1 to 0. The counting mechanism can be re-set at any time by the operation of the "re-set" contact which applies earth to the second arc of the uniselector bank to provide a homing circuit for the uniselector. When the standard 25-outlet uniselector is used, wear on the mechanism and the homing time can be reduced by arranging for two home positions, i.e. on the 1st and 12th contacts of the bank.

Impulse Counting by Relays. As an alternative to the uniselector scheme, it is possible to count

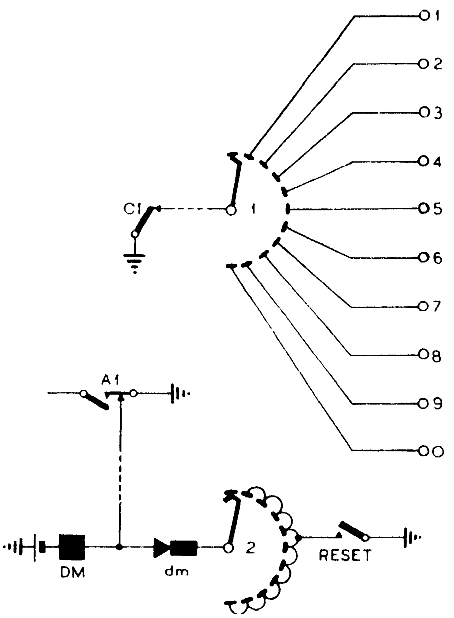


FIG. 232. IMPULSE COUNTING CIRCUIT WITH UNISELECTOR

any desired number of impulses by means of a group of ordinary telephone relays. Generally speaking, a relay counting circuit is capable of a much higher speed of operation than is possible with any form of mechanical selector. There is less noise, and the maintenance charges are lower. On the other hand, the design of an all-relay impulse counting circuit is not so simple as would appear at first sight. Most circuits require ten, or

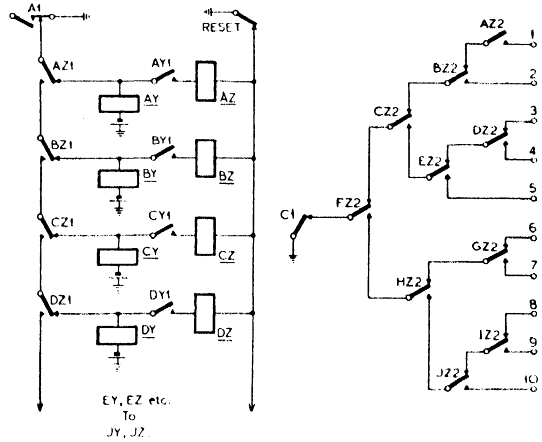


FIG. 233. TWO-STEP ADDITIVE IMPULSE COUNTING CIRCUIT

even more, relays to count a train of up to ten impulses. The resultant circuit has a fairly high initial cost, and is usually considerably more complex than the simple scheme utilizing a uniselector.

There is a large number of relay type impulse counting circuits in use. It is not possible to consider all of these circuits in the limited space available, but a representative section of the more common circuit elements is given below.

Two-step Additive Element. Fig. 233 shows part of a circuit which requires 20 relays for counting up to ten impulses. For simplicity the relays required for the first four impulses only have been shown in Fig. 233—the remaining relays (EY to JZ) are connected in exactly the same way.

$A1$ is the contact of the usual impulse accepting relay, and at the commencement of the first break impulse $A1$ releases to energize relay AY. $AY1$ completes the circuit for relay AZ, but the latter does not operate at this stage due to the presence of the earth from the $A1$ contact. At the end of the first break impulse, $A1$ re-operates and, by removing the earth, allows AZ to operate in series with AY. Both relays now hold to the common earth, and the impulsing contact is extended by $AZ1$ to the second element of the circuit. At the commencement of the next impulse, the release of $A1$ energizes relay BY, and at the end of this impulse BZ operates and locks. $BZ1$ now extends the impulsing contact to the third pair of relays (CY, CZ) and the process continues, impulse by impulse, in a similar manner. The contacts of the

various relays are arranged in tree formation as shown on the right of Fig. 233. For example, if three impulses have been received, relays AZ, BZ and CZ are all operated. During the interdigital pause, the C relay (not shown in Fig. 233) restores, and the $C1$ contact applies earth to the third marking terminal via $FZ2$, $\mathbf{CZ2}$, $EZ2$ and $DZ2$.

This simple two-step additive circuit is rather expensive due to the large number of relays required (i.e. two per impulse). Moreover, the contacts of the relays are arranged in a tree formation with a number of contacts in series for each marking condition. This tends to produce a somewhat high fault liability.

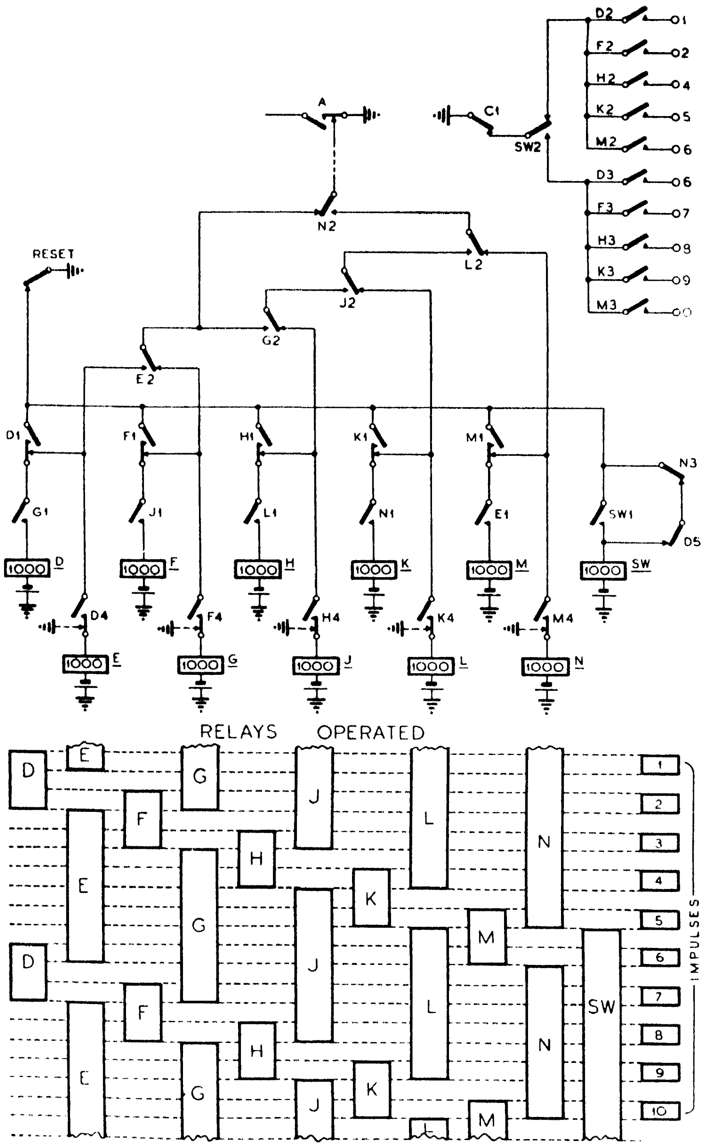


FIG. 234. STEP-BY-STEP CHANGEOVER IMPULSE COUNTING CIRCUIT

Step-by-step Changeover Element. Fig. 234 shows another method of counting the number of impulses in a train by means of a bank of relays. This principle has been used in a number of systems (e.g. the Relay System) and has proved to be very reliable. The main disadvantage lies in the comparatively large number of relays required. In Fig. 234 a total of 11 relays is required to count the number of impulses in a single digit train.

When the circuit is prepared for the acceptance of impulsing, relays E, G, J, L and N are pre-operated by the application of earth to the make-before-break contacts ($D4$, $F4$, $H4$, $K4$, $M4$). When $A1$ releases at the commencement of the first break impulse, earth is extended via **N2, L2, J2, G2, E2** and **G1** to operate relay D. **D1** provides a holding circuit for relay D under the control of the **G1** contact. The operation of **D4** transfers the holding circuit of relay E to the earth at $A1$.

At the termination of the first break impulse, E releases due to the re-operation of **A1**. The second impulse is now routed via $E2$ to relay F, which now locks to the common earth under the control of **J1**. The G relay holding circuit is transferred to the impulse contact earth by the operation of **F4** and the relay remains held until the termination of the second impulse. At this point G releases and at $G1$ releases D. $D4$ in turn allows the re-operation of E. The third impulse is now routed via $G2$ to operate relay H, **H4** transfers the holding circuit of J as before, and at the end of the third impulse relay H is held to the common earth, whilst relay J is released.

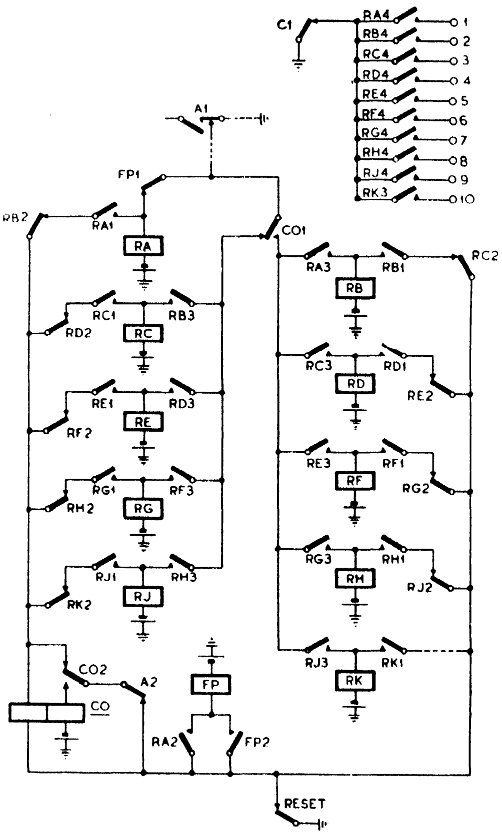
This process continues for each succeeding impulse. Theoretically, this method would require 10 pairs of relays to cater for a train of up to 10 impulses, but it is possible to effect some economies by utilizing only 5 relays with a changeover relay (SW) to differentiate between the first and second operation of the counting relays. At the end of the 5th impulse relays N and D are released together for the first time and at $N3$ and $D5$ operate relay SW to

change over the conditions for the second group of 5 impulses.

Contact $C1$ is a contact of the normal C relay (not shown in Fig. 234) which releases at the end of an impulse train. The release of $C1$ applies earth via $SW2$ and a contact of the D, F, H, K, or M relays to one of the marking terminals 1 to 0. Thus, the incoming train of Strowger impulses has been counted and an earth has been connected to one terminal of 10 to show the number of impulses in the train.

Step-by-step Changeover Element with Steering Relay. Fig. 235 is a further form of step-by-step counting element, the main difference between this and the previous circuit (Fig. 234) being the provision of a steering relay (CO) and of a first pulse relay (FP). The circuit requires one relay per impulse in addition to these two common relays. Like Fig. 234 this circuit provides for a simple arrangement of the relay contacts to provide the marking condition.

The first break impulse operates relay RA which locks to the common earth at contact ***RA*1**. Contact ***RA*2** completes a circuit for relay ***FP***, which also locks at ***FP*2** to the same common earth. ***FP*1** isolates the RA relay from the impulsing contact ($A1$) so that all subsequent impulses are directed to the various relays via the changeover contact ($CO1$). At the end of the first break impulse, the re-operation of the A relay removes the short circuit (at ***A*2**) from the CO relay so that the latter operates during the make period. ***CO*1** prepares the circuit for the energization of the RB relay (via ***RA*3**) on the next release of $A1$. When $A1$ releases for the second impulse, relay RB operates, and at the same time a holding circuit is provided for relay CO by the release of contact $A2$. The operation of RB breaks the holding circuit for RA (at ***RB*2**) and provides a holding circuit for itself via ***RB*1**. At the end of this second impulse, the re-operation of contact ***A*2** allows CO to release, so that the next break impulse is directed to the RC relay. RC locks to the common earth (via ***RC*1**) whilst ***RC*2** breaks the holding circuit of RB. At the end of the third impulse, the re-operation of ***A*2** allows relay CO to operate, thereby preparing the circuit for directing the next impulse to the RD relay. The process continues in this manner until the impulse train is complete. The restoration of the $C1$ contact during the inter-digital pause applies the marking condition to the appropriate terminal. The sequence of relay operations throughout a 10-impulse train is shown on the right of Fig. 235.



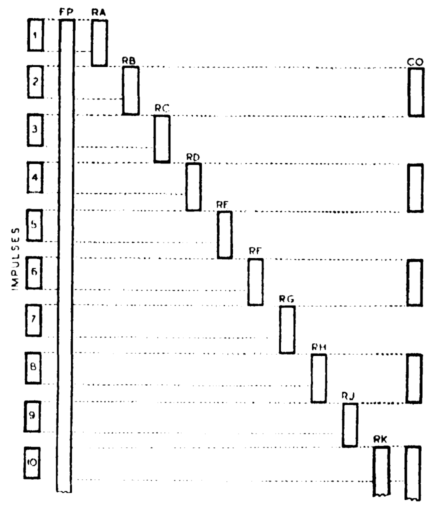


FIG. 235. STEP-BY-STEP CHANGEOVER COUNTING ELEMENT WITH STEERING RELAY

Progressive Additive Element. Theoretically it is possible to operate 4 relays in various combinations to count up to 15 different things. Ten of these combinations can be provided by operating not more than 2 relays at the same time. In practice it is extremely difficult to count up to 10 impulses by the use of the mathematical minimum of 4 relays. The main difficulty occurs due to the fact that when one relay operates at, say, the commencement of the first impulse, it is not possible to switch the circuit in readiness for the receipt of the next impulse until such time as the first impulse has terminated.

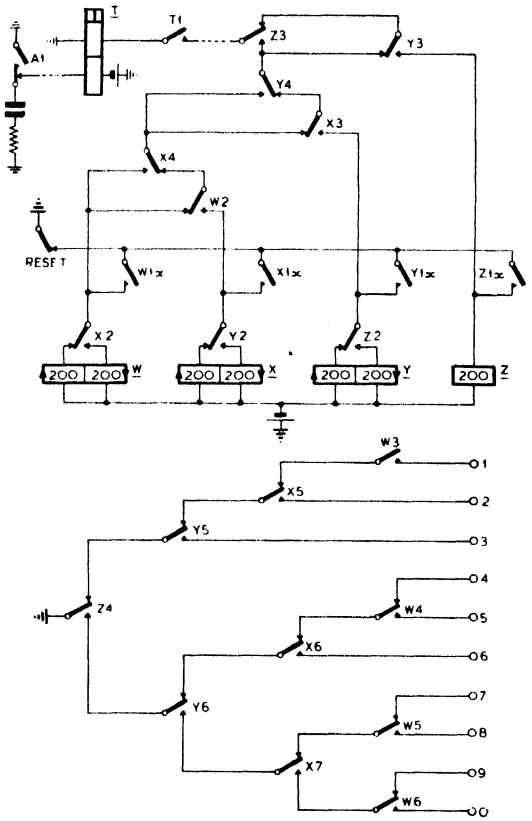


FIG. 236. IMPULSE COUNTING CIRCUIT USING HIGH SPEED CONTROL RELAY

Fig. 236 shows an interesting method of recording from 1 to 10 impulses by the use of four basic relays plus a fifth high speed relay. Contact *A*1 represents the usual contact of the impulse accepting relay, whilst relay *T* is a high speed relay which is capable of releasing during the transit time of the changeover contacts of the ordinary relays *W*, *X*, *Y* and *Z*. The two windings of *W*, *X* and *Y* are differentially connected whilst each relay has an "*x*" contact to provide a local locking circuit.

Prior to impulsing (i.e. with ***A*1** operated) the capacitor is discharged. At the first release of *A*1, the capacitor starts to charge in series with one coil of the *T* relay, which operates to the charging current. ***T*1** now completes a circuit for the energization of relay *W*, and the rising current in this circuit compensates for the decay of charging current in the first winding of *T* to maintain the relay in the operated position. In due course relay *W* operates, and there is a short interruption of the current in the *T* relay as the ***W*2** contacts change over. Relay *T*, being of the high speed type, releases during the momentary interruption of the current, and disconnects the holding circuit at *T*1 before the build up of current in the *X* relay circuit re-establishes the holding circuit. Relay *W* remains held at ***WX*1** whilst the quick release of *T* prevents the remaining part of the first impulse from affecting relay *X*.

The capacitor discharges to earth during the interval when the ***A*1** contact is operated between impulses, but when contacts *A*1 release for the second impulse, relay *T* is again energized by the charging current of the capacitor. The second closure of ***T*1** operates relay *X*, which holds at its "*x*" make contact. The changeover of ***X*3** now releases relay *T*, whilst ***X*2** switches the holding circuit of relay *W* from one winding to the other. The *W* relay is differentially wound and, in attempting to reverse its flux, the armature is repelled to normal where it remains.

The third impulse is recorded by the operation of relay *Y* which, at ***Y*2**, releases *X*. Similarly the fourth impulse is directed by ***Y*3** to operate relay *Z* which now releases *Y* by the changeover of contacts ***Z*2**. The *Z* relay holds for the duration of the count, and directs the fifth impulse to relay *W*. The sixth and seventh impulses are recorded by the operation of the *X* and *Y* relays respectively, the latter relay now becoming operated continuously until the circuit is re-set. This action continues until all four relays become finally operated to record the receipt of 10 impulses. The combinations are as follows:

Digit		Digit	
1	Relay *W*	6	Relays *X* + *Z*
2	,, *X*	7	,, *Y* + *Z*
3	,, *Y*	8	,, *W* + *Y* + *Z*
4	,, *Z*	9	,, *X* + *Y* + *Z*
5	Relays *W* + *Z*	0	,, *W* + *X* + *Y* + *Z*

The contacts of the 4 relays are arranged in tree formation as shown in the lower part of Fig. 236 to give the required marking conditions. The

counting circuit can be restored to normal by the operation of the "re-set" contact which breaks the holding circuit of all the relays.

Binary Impulse Counting Element. Fig. 237 shows another form of impulse counting circuit, based on the binary scale of computation. Any number, such as 432, implies that there are 4 hundreds, 3 tens and 2 units. Thus,

$$432 = (4 \times 100) + (3 \times 10) + (2 \times 1)$$

Each term of the right-hand side of this expression contains a power of 10, and can be expressed mathematically:

$$432 = (4 \times 10^2) + (3 \times 10^1) + (2 \times 10^0)$$

Although 10 is the base most commonly used, other bases can be adopted if desired. If the base 2 is used, the digit 1 can be expressed as 2^0, digit 2 as 2^1, digit 3 as $2^1 + 2^0$, and so on. The second column of the schedule on the right gives the binary (or scale of 2) equivalents of the digits 1 to 10.

It will be noted that there are now only four different "units" (i.e. 2^0, 2^1, 2^2, and 2^3) which can be used either singly or in combination to represent each of ten different numbers.

If it is possible to design a circuit so that one particular relay operates for each of the four different conditions, then this circuit can be made to count up to 10 impulses by operating one, two or three relays. In Fig. 237 the T relay is operated for a time equal to 1 impulse period (i.e. 2^0), the V relay is operated for the time occupied by 2 impulses (i.e. 2^1), the X relay is operated over a period covering 4 impulses (i.e. 2^2), whilst the Z relay is operated for a time equivalent to 8 impulses (i.e. 2^3). The circuit is so arranged that the relays are operated during receipt of an impulse train, in accordance with the third column in the tabulation below.

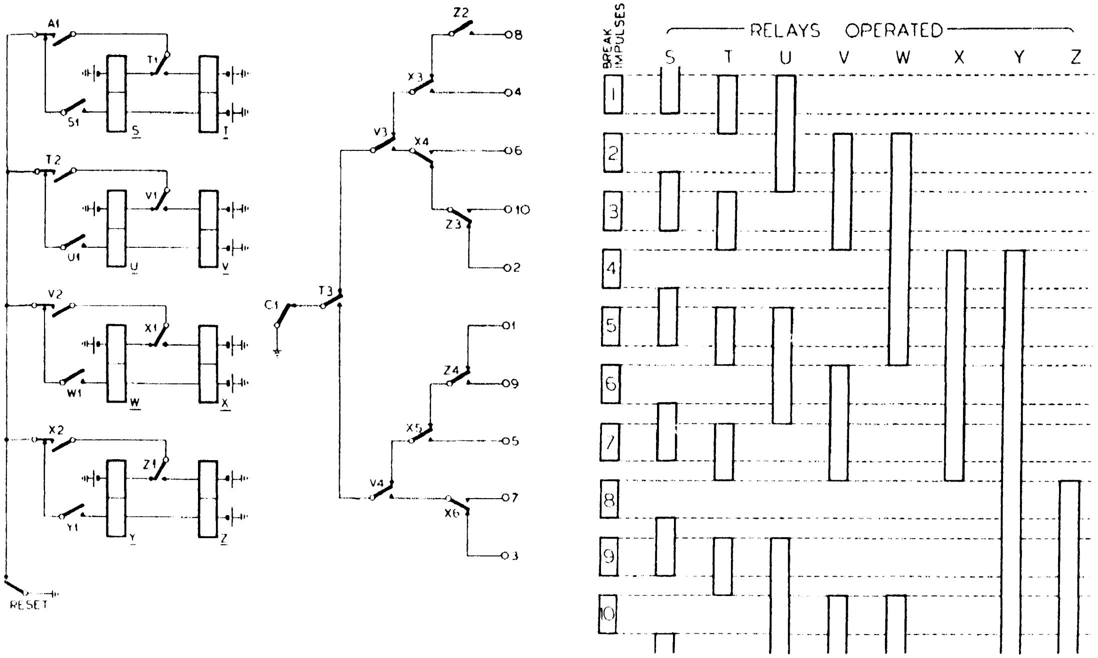


FIG. 237. BINARY IMPULSE COUNTING CIRCUIT

Impulse No.	Binary Equivalent	Relays Operated
1	2^0	T
2	2^1	V
3	$2^1 + 2^0$	$V + T$
4	2^2	X
5	$2^2 + 2^0$	$X + T$
6	$2^2 + 2^1$	$X + V$
7	$2^2 + 2^1 + 2^0$	$X + V + T$
8	2^3	Z
9	$2^3 + 2^0$	$Z + T$
10	$2^3 + 2^1$	$Z + V$

The counting circuit of Fig. 237 really consists of four sub-elements, each of which is basically a step-by-step changeover circuit. The binary circuit is rather expensive in relays, and has the disadvantage of requiring a more or less complex

marking tree. On the other hand, this same group of 8 relays will, if required, count up to 16 impulses without additional apparatus. The detailed circuit operation should be clear from the relay sequence chart on the right-hand side of the diagram.

Impulse Storage. The circuits so far described for the *counting* of the number of impulses in a train can all be used for impulse *storage* purposes. Usually storage facilities for 4 or more digits are required. This necessitates some device for switching each impulse train to a different group of relays or to a different storage uniselector. The

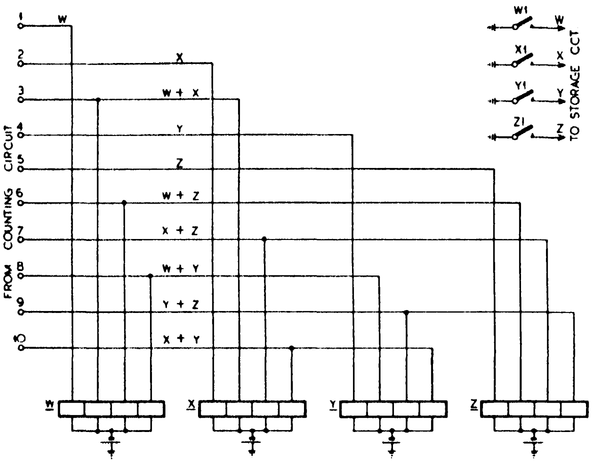


FIG. 238. CIRCUIT FOR CONVERTING FROM 10-POINT MARKING CONDITION TO 4-WIRE COMBINATION SIGNALS

switching can be done by means of relays so arranged that the impulsing contact is switched to the next group of receiving relays when the C relay releases at the end of each impulse train. A relay type digit switching circuit tends to become somewhat complex, and it is generally preferable to distribute the impulse trains to the correct storage groups by means of a *digit distributor* of the uniselector type.

Where uniselectors are used for counting the number of impulses in each train, it is usual to carry out the process of impulse counting and digit storage at the same time, i.e. to count the impulses on the uniselector which is to be used for storing the digit. When, however, a chain of relays is used for impulse counting, it is often better to have a separate impulse counting unit, and to utilize this same unit for each successive impulse train, the marking conditions being passed to separate storage groups at the end of each digit. By this means it is possible to utilize a simple circuit employing the theoretical minimum of 4 relays for storage purposes.

Relay Type Impulse Storage Circuit. The relay type of impulse counting circuits described in previous paragraphs are all more or less complex. This is primarily due to the fundamental requirement that switching to the next receiving element can take place only *between* successive impulses and not *during* the actual transmission of the impulse. These conditions do not apply to relay type impulse storage circuits. Basically three separate and distinct conditions can be set up in a group of two storage relays (i.e. one relay operated, the other relay operated, or both relays operated). Similarly, a group of three storage relays can be used to provide up to a total of seven different conditions. In automatic telephony, each digit may consist of any one of ten different conditions, and this requires a basic minimum of four relays for storage purposes. If the relays are designated W, X, Y and Z, the following combinations can be used to indicate the ten different digits:

Digit 1	W	Digit 6	$W + Z$
,, 2	X	,, 7	$X + Z$
,, 3	$W + X$	,, 8	$W + Y$
,, 4	Y	,, 9	$Y + Z$
,, 5	Z	,, 0	$X + Y$

It will be noted that all of these combinations utilize the relays either singly or in pairs. Additional combinations can be obtained, if required, for miscellaneous purposes, by the adoption of 3 and 4 relay combinations (i.e. WXY, WXZ, etc.).

The adoption of the basic 4-relay storage circuit requires that the impulse counting system should transmit the marking condition for each digit over one or two of four wires to the storage relays. If the counting circuit is of the relay type, then the contact tree of the counting circuit can be made to give these conditions direct (i.e. if the digit 3 is set up in the counting circuit, marking conditions will be applied to the W and X leads of the storage circuit). If, on the other hand, the counting circuit is of the uniselector type, the marking condition will be forwarded to the storage circuit over one of ten wires, depending upon the digit received. In these circumstances it is necessary to provide a conversion circuit on the lines of Fig. 238 between the impulse counting circuit and the relay storage group. This conversion circuit requires four additional relays, each of which must have four windings to obtain the necessary combinations.

Fig. 239 shows a circuit suitable for storing a 4-digit number. It consists essentially of four

groups of storage relays, one group (*MW* to *MZ*) for the thousands digit, a second group (*CW* to *CZ*) for the hundreds digit, a third group (*DW* to *DZ*) for the tens digit, and a fourth group (*UW* to *UZ*) for the units digit. At the termination of the first impulse train, an earth is applied (from the impulse counting circuit) over one or more of the four marking wires in accordance with the above system can be re-set by the disconnexion of the storage relay holding circuit and by the completion of the homing circuit (not shown in Fig. 239) of the digit distributor. The contacts of each group of storage relays are arranged in the tree formation shown to provide the appropriate marking conditions to the circuit which will later deal with the stored impulse trains. (Fig. 239 shows only

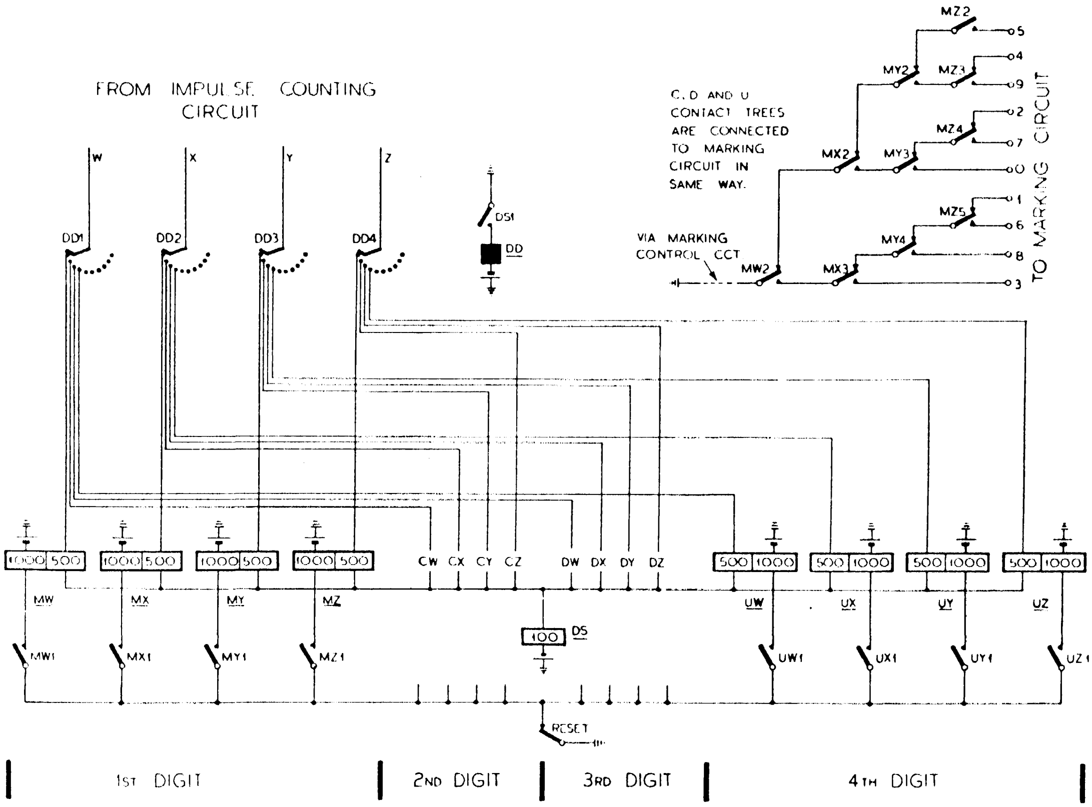


FIG. 239. RELAY STORAGE CIRCUIT FOR 4-DIGIT NUMBER

tabulation. These earths are extended via the wipers and 1st contacts of the digit distributor switch to operate the required combination of the *MW*, *MX*, *MY* and *MZ* relays. Relay *DS* is in series with this circuit and operates to energize the digit distributor magnet at *DS*1. When the marking earths are removed *DS* releases, but the storage relays hold over their second coils to the common earth. The release of *DS*1 allows the digit distributor to make one step so that the next marking condition is received on the *CW* to *CZ* relays.

The tens and the units trains are dealt with in a similar manner, so that the whole 4-digit number is stored on the four groups of relays. The storage one such tree. There are, of course, similar trees for each of the three remaining groups.)

Impulse Storage on Uniselectors. Fig. 240 shows an alternative method of storing four (or more) impulse trains by means of a group of uniselectors. It has been seen that, where uniselector storage is to be adopted, the Strowger impulses can be used to step the storage uniselectors direct. As in the previous circuit, a digit distributor is required to divert the impulse trains to the various storage uniselectors. Where 25-point uniselectors are used, however, spare contact positions of the final digit uniselector can be used for distribution of the impulse trains to each of the preceding uniselectors. This is possible because the digit distributor is not

required to make any further steps after the storage of the final digit.

Fig. 240 illustrates a 4-digit storage system where the thousands digit is stored on uniselector M, the hundreds digit on uniselector C, the tens digit on

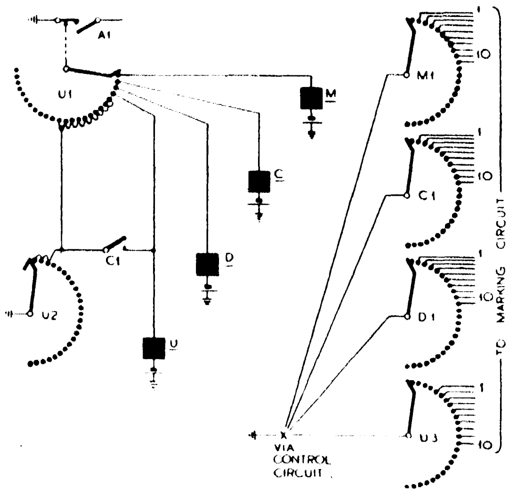


Fig. 240. 4-digit Storage Circuit Using Uniselectors

uniselector D, and the final units digit on uniselector U. The first 4 contacts of the units uniselector (U) are used as the digit distributor. When the circuit is prepared in readiness for impulsing, an earth is applied to the magnet of the units uniselector via arc 2 of its own bank, and contact **$C1$**. The uniselector mechanism is reverse-acting, and the energization of the magnet at this stage does not cause the mechanism to step.

During the first digit the release of contact $A1$ at each break impulse transmits an earth to step the driving magnet of the M uniselector. During the interdigit pause, relay C falls away to disconnect the U magnet coil, thereby allowing the units uniselector to make one step. The second train is directed to the magnet of the C uniselector and, at the end of this train, C again releases to cause the units uniselector to make a further step. The process continues for as many digits as are required.

Impulse Machines. The impulses required for electrical regeneration and similar circuits are usually obtained from special *impulse machines* which are designed to give a constant supply of impulses of the correct ratio and at the correct frequency. The impulse machines often run continuously and are common to a number of circuits. It is important that the impulse springs should be connected to the transmitting circuit only during the interval *between* successive break impulses. If this were not arranged, then there would be a grave danger of a clipped first impulse being transmitted. This necessary co-ordination is obtained by providing, for each pair of impulsing springs, a second pair of springs known as *magnet springs*. (The impulse springs themselves are often known as *loop springs*.) The magnet and loop springs are so phased that the loop springs are closed when the magnet springs open, and the latter are used in the associated circuit to ensure that the loop springs are closed prior to the transmission of the first break impulse.

Fig. 241 shows a typical motor-driven impulse machine, which is mounted horizontally on the apparatus rack (see Fig. 156). The long spindle has 10 pairs of fibre cams clamped to it. These cams control 10 pairs of impulsing springs and the associated 10 pairs of magnet springs. The cams associated with the loop springs provide the standard $66\frac{2}{3}$ per cent break, whilst the magnet springs are arranged to be open for $33\frac{1}{3}$ per cent of the total impulse time (Fig. 242). The spindle and cams are rotated by a $\frac{1}{8}$ h.p. battery-driven motor, and the pairs of cams are staggered round the spindle to maintain the load on the driving motor as constant as possible. The drive between the motor and the spindle is taken through a

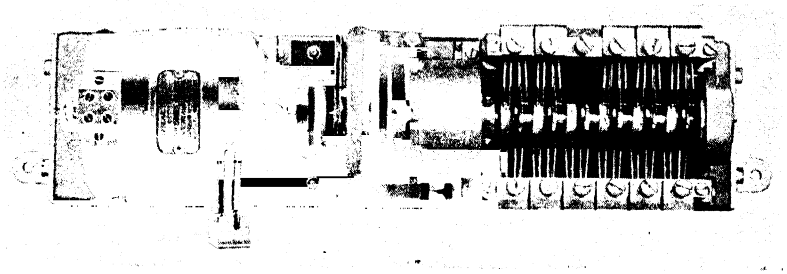


Fig. 241. Motor-driven Impulse Machine

clutch which is designed to slip at 600 r.p.m. Thus the spindle rotates 10 times per second to produce impulses at the standard frequency.

Fig. 243 shows an alternative type of impulse machine. The driving mechanism consists of a long heavy bar, which engages with the moving springs of ten pairs of loop and magnet impulsing springs. The bar is fitted with an armature at one end, and an electromagnet provides the

motive power for drawing the bar to one side against the tension of a system of restoring springs. An interrupter spring is actuated by the bar when it is attracted so that, when the magnet is energized, the bar vibrates in the same manner as the striker of a trembler bell. The mass and stiffness of the moving system are so adjusted that the machine vibrates under self-interrupted drive at the standard frequency of 10 I.P.S.

A start and alarm circuit is provided for each impulse machine. This circuit permits the starting of the machine when it is required for use, and also gives an alarm in the event of failure of the impulse springs.

Vibrating Relay Impulse Generators. In some circumstances it is not convenient (for economic or

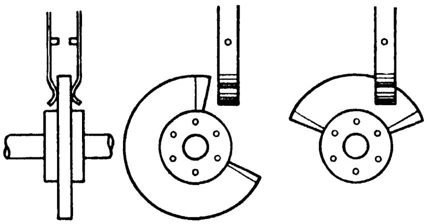


FIG. 242. LOOP AND MAGNET SPRING CAMS OF MOTOR-DRIVEN IMPULSE MACHINE

other reasons) to provide an impulse machine. An alternative method is to provide a vibrating relay or a group of interacting relays. In some cases the timing is obtained by the operate and release lags of relays, whilst other devices rely upon mechanical resonance to give the correct frequency of vibration. The element illustrated in Fig. 244 has been used in a number of recent circuit designs to provide a simple method of generating Strowger impulses at the standard ratio and frequency. When the start condition is applied (by the closure of *ST1*) the current commences to grow in the 1500 Ω coil of relay *A*. At the same time, there is a current through the 500 Ω coil to charge the bank of capacitors (*QA*). The connexions are such that these two currents are mutually opposing, and the resultant flux in the relay core during the initial stages is consequently low. As the bank of capacitors becomes charged, the current through the 500 Ω coil progressively falls, but the opposing current in the 1500 Ω coil is rising in accordance with Helmholtz's Law. After a delay period, therefore, the relay operates and at *A*1 completes a circuit for the high speed relief relay *AA* and at the same time disconnects the initial operating circuit of relay *A*.

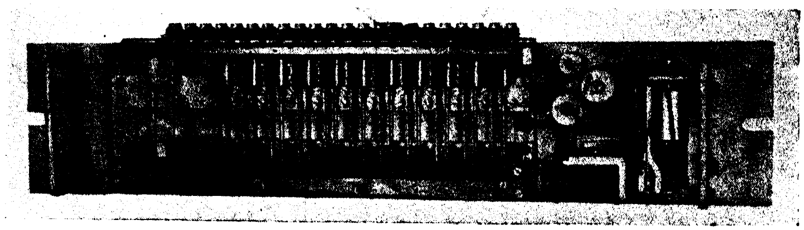


FIG. 243. RECIPROCATING TYPE IMPULSE MACHINE

When the earth is disconnected from the *A* relay, the bank of capacitors commences to discharge through the 500 Ω and the 1500 Ω coils of relay *A* in series. The direction of this current is such that the magnetic effect of both windings is additive. This prolongation of the current in the *A* relay windings maintains the relay until such time as the capacitors have substantially discharged. The *A*1 contacts now release and the cycle of operations is repeated. Contacts of the *AA* relay provide make and break impulses, the frequency and ratio of which are largely determined by the operating and release characteristics of relay *A*. These characteristics in turn are controlled mainly by the inductance and resistance of the *A* relay itself, and by the capacitance of the bank of capacitors *QA*.

It is found that the adjustments of the relay have comparatively little effect on its operating and release times, and hence the circuit is capable of providing impulses of a uniform character over a prolonged period. One advantage claimed for

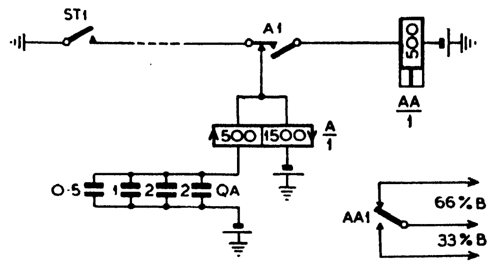


FIG. 244. IMPULSE GENERATOR USING DIFFERENTIALLY WOUND RELAY

this circuit is that the impulse generating element can be started and stopped after each impulse train, and that when so used the first impulses of the train are of substantially similar character to the later impulses. This characteristic of the circuit obviates the necessity of control relays

(which are necessary with machine generated impulses) to ensure that the impulse springs are closed at the time the impulsing circuit is applied to line.

Re-transmission of Stored Impulse Trains. Fig. 245 shows a typical circuit arrangement for re-transmitting a series of stored impulse trains. (The storage system can be either of the relay or of the uniselector type.) The circuit utilizes machine generated impulses, two impulsing spring sets being required per circuit. The first spring set (the loop springs) gives a 66⅔ per cent break period and is used for direct application to the outgoing line, whilst the second spring set (the magnet springs) has a 33⅓ per cent break period and is used for controlling the send switch driving magnet. The spring sets are arranged so that, whilst the loop springs are closed, the magnet springs are open, and vice versa. This arrangement, in conjunction with an impulse guard relay, ensures that broken or mutilated impulses cannot be sent out to line.

A control switch (*C*1) applies earth in turn to the chain of contacts formed by the storage group of each digit. The chain contacts are in turn connected to an arc (*S*1) of the send switch. The arrangements are such that if, say, digit 3912 is set up in the storage relays, the control switch first applies an earth through the thousands storage group to mark the fifth contact of the send switch bank. When the control switch wiper is moved to the second position, the earth is applied to the storage circuit of the hundreds group to mark the eleventh contact of the send switch bank, and so on.

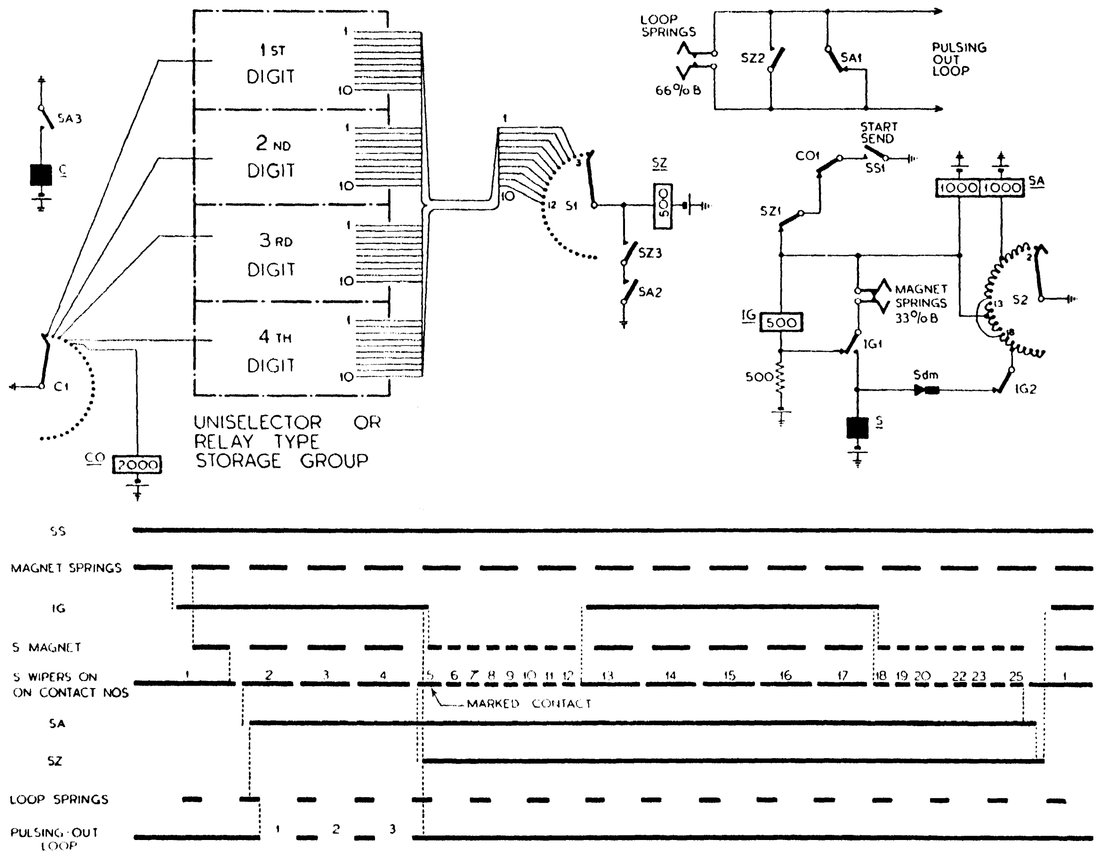


FIG. 245. CIRCUIT FOR RE-TRANSMISSION OF STORED IMPULSE TRAINS

Initially, the outgoing loop is completed by contact *SA*1 to seize the distant selector circuit. The start send relay (*SS*) is operated when it is desired to commence pulsing out. ***SS*1** applies an earth to the *IG* relay but, if at this time the magnet springs are closed, the *IG* relay cannot operate due to the short circuit across it formed by the magnet springs. When the magnet springs open, *IG* operates and at ***IG*1** prepares the circuit for the

send switch driving magnet. The next closure of the magnet springs energizes the send switch but the wipers do not step until the magnet springs again reopen. The wipers of the send switch now step from the home contact and relay *SA* is operated. Contacts ***SA*1** now open, but the outgoing loop is now maintained by the loop springs of the impulse train which at this time are closed.

The send switch driving magnet is stepped by each operation of the magnet springs and the wipers of the send switch move round at a speed of 10 steps per second. Throughout this time impulses are being transmitted by the loop springs. In due course the *S*1 wiper encounters the marking earth extended through the storage relay contacts. *SZ* now operates and at ***SZ*1** disconnects the driving circuit of the send switch magnet. ***SZ*2** short-circuits the loop springs to prevent any further impulses being sent to line, whilst ***SZ*3** provides a holding circuit for *SZ*. The operation of ***SZ*1** also releases the *IG* relay which at *IG*2 completes a self-drive circuit for the send switch magnet from the earth at the *S*2 wiper. This drive continues until the *S* wipers reach the 13th contact of the bank. Contacts 13 to 17 of the *S*2 bank are commoned together and are connected to the *IG* relay and the second coil of *SA*. *IG* now reoperates at the first break of the magnet springs and at ***IG*1** provides a further stepping circuit for the *S* magnet under the control of the impulse machine. Thus, the send switch continues to step at 10 I.P.S. until the wipers reach the 18th contact, when the holding circuit for *IG* is broken and the stepping circuit is replaced (at *IG*2) by a homing circuit under the control of the *Sdm* springs. The 5 steps (from contact 13 to contact 18) at 10 I.P.S. ensure that there shall be a minimum pause of 500 msec between the transmission of successive digits. The interdigit pause is, of course, somewhat greater than 500 msec due to the additional time when the send switch moves under self-drive conditions from the marked contact to contact 13 and also from contact 18 to contact 25.

When the send switch returns to normal, relay *SA* releases and at *SA*2 releases *SZ*. The conditions on the outgoing impulsing loop are now restored to normal and the release of *SA*3 allows the control switch to move to the second rotary position. The release of *SZ* re-establishes the circuit for relay *IG*, and the circuit operation for the second and subsequent trains is a repetition of the above. A *CO* relay, connected to the bank of the control switch, operates when all stored impulse trains have been transmitted and prevents any further transmission of impulses.

The lower part of Fig. 245 shows the sequence of operations during the transmission of the digit "3."

Impulse Regenerator With Capacitor Storage. Fig. 246 shows an interesting suggestion for storing and regenerating a series of impulse trains. The storage element consists of a multi-element capacitor (*Q*1–*Q*10) together with two standard uniselectors *R* and *S*. An incoming impulse train steps the *R* magnet at each break impulse, so that

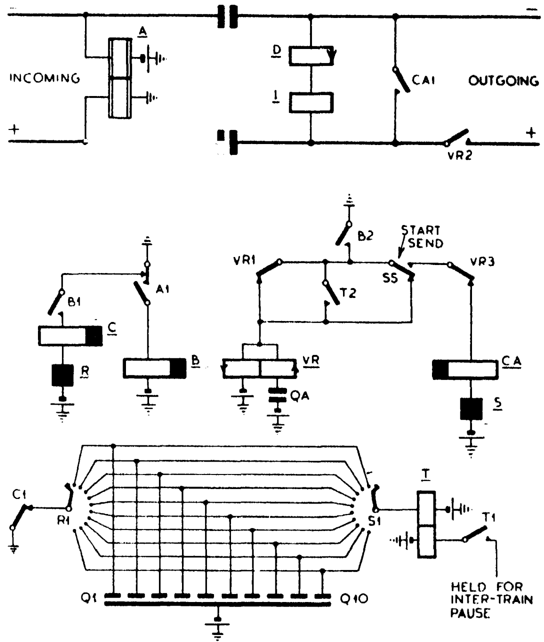


FIG. 246. ELEMENTS OF ELECTRICAL IMPULSE REGENERATOR WITH CAPACITOR STORAGE, AND VIBRATING RELAY IMPULSE GENERATOR

the *R*1 wiper moves round the bank as the incoming impulses are received. At the end of the impulse train, the *C* relay releases, and at *C*1 applies earth to one of the capacitor elements depending upon the position of the *R*1 switch. The second impulse train again steps the *R* switch, and at the end of this train the release of *C*1 again applies the marking potential to one of the capacitor elements. This process continues for each digit.

The regenerated impulses are provided by a vibrating relay *VR* of the type already considered in Fig. 244. When the circuit is seized, the closure of the ***B*2** contact energizes *VR* which, at ***VR*2,** completes the outgoing loop. At the appropriate time, the Start Send contact (***SS***) is operated, thereby disconnecting the holding circuit for *VR*.

VR restores after a delay period, and at *VR*3 extends the **B2** earth to operate the *S* switch. At the same time *VR*1 restores the operate circuit for relay *VR* and after a further period of delay the re-operation of *VR* disconnects the pulse of current to the send switch magnet. In this way the send switch is stepped at a frequency of 10 I.P.S. whilst, at the same time, the *VR*2 contact transmits impulses of the correct ratio to line.

Relay *T* is connected to the wiper of the *S*1 bank and, when the send switch reaches a contact marked by a charge on the capacitor, the *T* relay operates and at the same time provides a circuit for the discharge of the capacitor. Contact **T2** holds the *VR* relay to arrest the stepping of the send switch and to terminate the impulse train in the outgoing loop. Arrangements are also necessary for the holding of *T* for a period in order to give an adequate intertrain pause.

Care must be taken in the detailed circuit arrangements to ensure that the marking condition of one digit is removed before the *R*1 wiper again reaches the marked contact. Similarly the circuit must make sure that, under the most adverse conditions (i.e. very low incoming impulse frequency), the *S* switch wipers always lag behind the *R* switch wipers.

Counting of a Series of Impulse Trains. It is sometimes necessary to count a number of consecutive digits in order to provide a correct discriminating signal which can only be determined after the dialling of a number of impulse trains. As will be seen later, such discrimination may be required to determine the appropriate meter fee, to determine whether a certain type of call shall be barred access to certain routes, etc. Such circuits are generally known as *discriminators*, and discrimination is effected by applying a marking condition when *all* the required impulse trains have been received. The absence of separate storage for *each individual digit* permits of a comparatively simple counting circuit.

Fig. 247 shows a typical digit counting circuit in which the impulse trains are counted on a single uniselector mechanism. In the example given, the uniselector has 5 effective arcs, and facilities are provided for switching the marking condition from arc to arc as required. The circuit is arranged so that the wipers of the uniselector make one step for each impulse received, the impulses of the second and subsequent trains merely causing the wipers to continue stepping around the bank. If, for example, a subscriber dials the digits 765, the wipers (which are standing on the first bank contact prior to impulsing) are moved to contact 8 at the end of the first digit, to contact 14 at the end of the second digit, and finally rest on contact 19 at the end of the third digit.

There are 25 bank contacts on each of the 5 uniselector arcs, i.e. there is a total of 125 bank contacts to which marking conditions can be applied. This does not, however, mean that a 5-level uniselector will cater for 125 different dialling codes. Certain of the bank contacts must be reserved for providing wiper switching signals, whilst other contacts must be left spare to prevent false marking or wiper switching between the successive digits of the various codes. For example, if contact 19 of the first arc is used to provide the marking condition for dialling code 765, it is clear that the 8th and 14th cannot be used either for wiper switching or for marking any other dialling code. In practice a 5-arc uniselector may cater for something of the order of thirty 3-digit codes, but the capacity in any particular case does, of course, depend considerably upon the actual values of the various digits.

Fig. 247 shows typical connexions of the uniselector banks for four different dialling codes. For purposes of explanation it is assumed that the dialling of the code 67595 would route the caller to an exchange outside the range of the multi-metering equipment. Provision must, therefore, be made to bar direct automatic access on this route.

*A*1 is the normal impulsing contact, and is arranged to step the uniselector driving magnet during each break impulse. Assuming that the initial digit is 6, the wipers are stepped to the 7th position at the end of the first impulse train. The 7th contact of arc No. 1 is connected to relay *SA*, and during the interdigit pause relay *C* releases to apply an earth to the first wiper and thence to operate *SA*. *SA* locks to a local circuit and at ***SA*2** prepares for the marking condition to be applied to the second wiper at the end of the second impulse train. The dialling of the next digit (7) steps the wipers to the 14th position and, when *C*1 releases, the earth applied via *C*1, ***SA*2**, and No. 2 wiper operates relay *SB*. *SB* locks, and at ***SB*2** switches the marking circuit to the third arc. On the dialling of the third digit (5), the wipers are stepped to the 19th position, and, during the intertrain pause, relay *SC* is operated. The fourth digit (9) causes the uniselector wipers to complete one half revolution and to step to contact No. 3. At the end of this train, relay *SD* is operated, and the final digit (5) is received on the 5th arc to step the wipers to the 8th rotary position. This particular bank contact is cross-connected to a terminal, so that the earth from *C*1 can operate the required discriminating relay (in this case "all calls barred").

Although, in the above example, the cross-connexions are such that wiper switching takes place at the end of each digit, this is not necessarily as, and two or more digits can be received on the some arc of the switch. Codes of any reasonable number of digits can be accommodated, but it is important that the connexions for wiper switching should be very carefully arranged in order to obtain the maximum number of codes (i.e. the *minimum* number of wiper switching contacts). When the discriminator has completed its work, the counting uniselector is restored to normal so that the wipers rest on the first contacts in readiness for the next call.

Translation. In certain switching schemes it is necessary to convert the digits dialled by the calling subscriber to an entirely different series of digits to route the call through the automatic switching equipment. The process of sending out a new and different series of impulse trains on receipt of a dialling code is known as *translation.*

Fig. 248 shows a method of effecting translation by the use of a 2-motion selector. The Strowger switch of the normal type has a total of 100 wiper positions and will cater for 100 different dialling codes. It is possible to cross-connect each bank contact of the 2-motion selector to any desired contact of the send switch bank. Thus, when a marking condition is applied through the 2-motion selector wipers to a particular bank contact, this marking condition is extended to the required contact of the send switch. A separate wiper and bank on the 2-motion selector is necessary for each digit required in the translation. Thus, if as in Fig. 248, a total of 6 banks is provided on the 2-motion selector, it is possible to provide a maximum of 6 digits in the translation by arranging for the marking condition to be applied to each of the 2-motion selector wipers in turn.

For purposes of illustration, Fig. 248 shows the cross-connexions required to provide for the sending out of the digits 5196 on receipt of a dialling code consisting of the digits 28. The impulsing contact ($A1$) applies earth to the vertical magnet of the 2-motion selector via a digit distributor switch. At the end of vertical stepping, the circuit is so arranged that the digit distributor makes one step to route the next impulse train to the rotary magnet.

The start send contact is operated when it is desired to commence the transmission of the translated routing digits. An earth is now applied to the IG relay circuit, and this relay operates on the first break of the magnet springs. $IG3$ completes the circuit for the send switch driving magnet, which proceeds to step under the control of the magnet impulse springs and removes the short circuit from the loop springs at the $S2$ arc. In due course wiper No. 4 of the send switch reaches contact No. 7, which is cross-connected to the 8th contact on the 2nd level of the first 2-

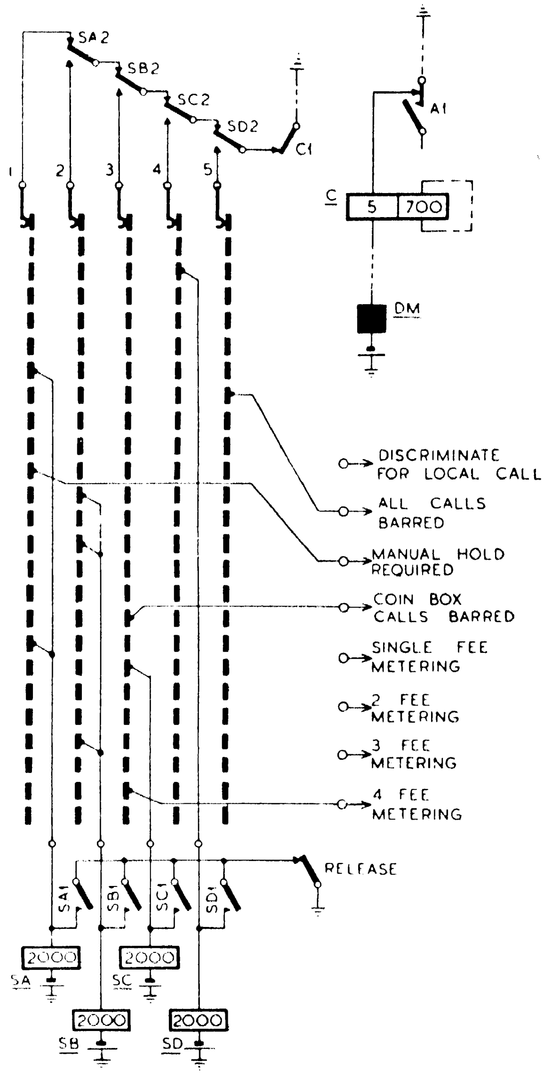


FIG. 247. ELEMENTS OF DIGIT DISCRIMINATION CIRCUIT

motion selector bank. No. 1 wiper is standing on this contact, and earth is extended from the control switch (CN) via the first wiper and bank to contact 5 of the $S4$ arc. Relay SZ operates to the earth and locks via $SZ1$ to the earth on the $S3$ arc. $SZ3$ breaks the circuit of the CN driving magnet. The CN switch now makes one step to

transfer the marking condition from bank No. 1 to bank No. 2 of the 2-motion selector. *SZ2* breaks the send switch stepping circuit, thereby allowing drive to provide the interdigit pause. When contact 19 is reached, the self-drive is restored until such time as the *S* switch reaches its normal

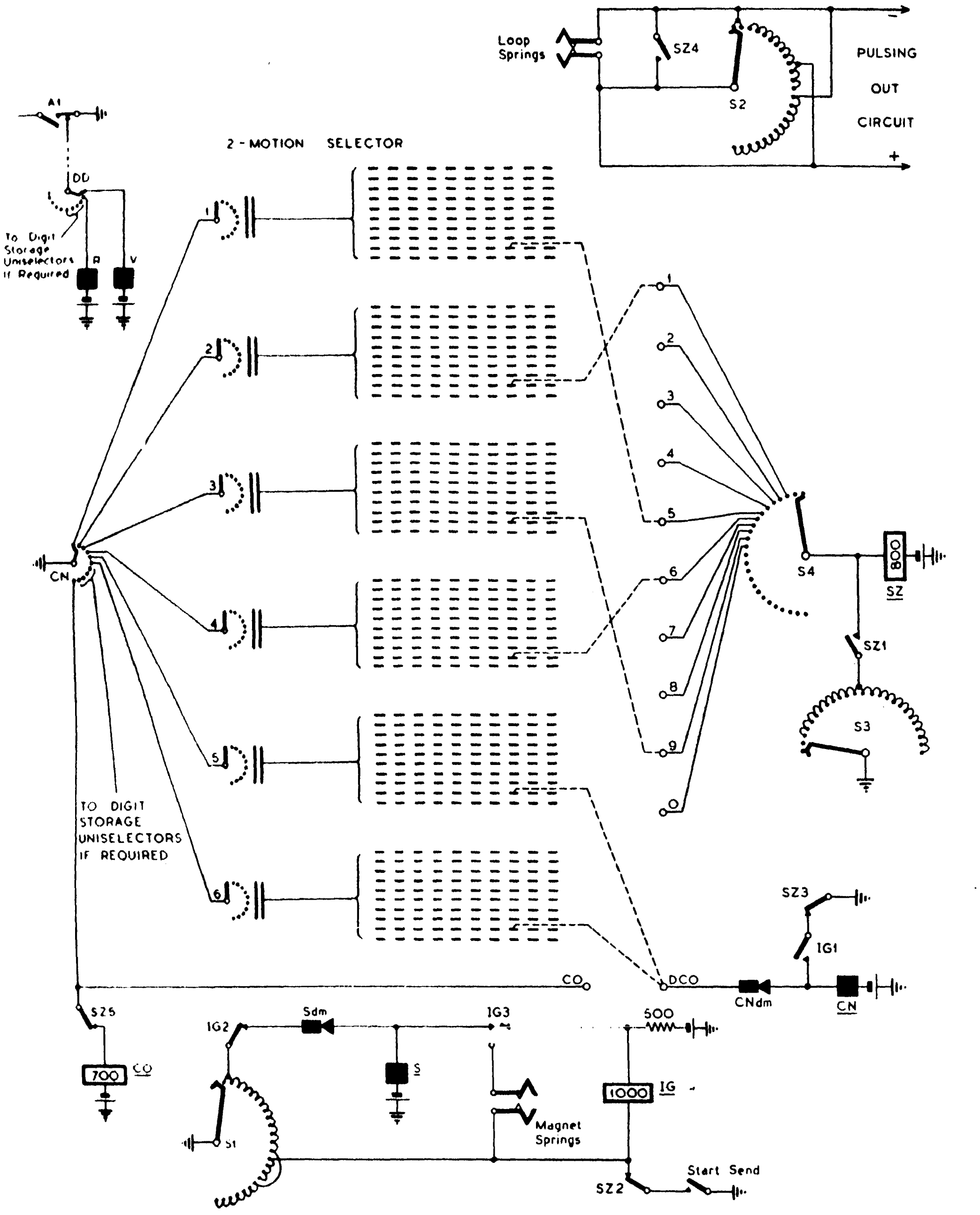


FIG. 248. CIRCUIT FOR OBTAINING UP TO SIX TRANSLATED DIGITS

relay *1G* to release and the *S* magnet to drive via its own interrupter contacts from the earth at the *S1* arc. When the wipers reach contact No. 15, th self-drive circuit is replaced by a slower position. The restoration of *SZ2* allows the send switch to operate for the second digit, and the process is continued for each succeeding impulse train.

It has been seen that the arrangement shown in Fig. 248 provides for a total of 6 digits in the translation. The maximum number of 6 digits will not, however, be required for all the dialling codes. If a smaller number of digits is required, then the unused banks of the 2-motion selector are cross-connected to the *DCO* terminal. When the marking condition is applied to any bank so connected, the control switch steps under self-interrupted drive to the next bank.

Translation facilities are normally required only on those digits which are required to route the caller through to the numerical selectors at the called exchange. The introduction of translation on the routing digits necessitates storage and re-transmission of all later digits, even although such digits are re-transmitted in their original form. The calling subscriber is unaware of the translation process and proceeds to dial each digit without pausing between consecutive operations of the dial. It is not possible to commence the transmission of the routing digits until the code to be translated has been fully received. There is clearly no time available for the translated impulse trains to be sent out before the subscriber dials his next digit. It follows that facilities must be provided for receiving and re-transmitting *all* digits wherever translation facilities are required. The storage and re-transmission of digits has already been dealt with in the preceding paragraphs. If a uniselector system of storage is adopted, the uniselector driving magnets can be connected to the 3rd and following digits of the digit distributor in Fig. 248. Similarly, the marking condition for re-transmission can be applied to the 7th and subsequent contacts of the control switch.

Fig. 248 has assumed the use of a 2-motion selector in order to give translation facilities on a total of 100 dialling codes. If 10 or less dialling codes are required, the 2-motion selector can be replaced by a uniselector type mechanism, the number of wipers required being determined by the maximum number of routing digits required in the translation.

EXERCISES VI

1. Under what circumstances is it necessary to provide an impulse repetition bridge? Give a diagram of an elementary capacitor type bridge and explain the functions of the various relays.

2. In what ways can a capacitor type repetition bridge produce impulse distortion? How can such distortion be minimized?

3. What do you understand by the phrases "initial pick-up" and "subsequent pick-up"? Explain how these factors limit the length of junction over which direct dialling is possible and what circuit devices can be used to improve the dialling limits.

4. Give a diagram of a transformer type impulse repetition bridge. What are the advantages of this type of bridge as compared with the capacitor type bridge?

5. Explain concisely the difference between "impulse correction" and "impulse regeneration." Draw the basic element of an impulse correction circuit suitable for giving predetermined minimum-break and minimum-make impulse periods. What are the limitations of such a circuit?

6. Describe briefly the essential features in the construction of an impulse regenerator. Suggest in what circumstances an impulse regenerator can be usefully employed, illustrating your answer by means of simple trunking diagrams. (*C. & G. Telephone Exchange Systems III*, 1948.)

7. Show how a train of from one to ten impulses can be counted by means of a group of relays. How would you arrange the contacts of the relays to provide suitable signals to a separate 4-relay storage circuit?

8. Give a diagram of a circuit suitable for storing a 4-digit number on a series of uni-selectors.

9. What additions must be made to the diagram of Question 8 to provide for the re-transmission of the stored impulse trains? In what ways is it necessary to co-ordinate the operation of the storage and transmission elements?

10. What is "translation"? Show how one digit from the subscriber's dial could be used to provide four separate impulse trains to route the call to the required destination.

CHAPTER VII

HUNTING, TESTING, AND SWITCHING CIRCUITS

It has been seen in Chapter I that when a subscriber lifts his receiver to originate a call, his uniselector is required to search over the available trunks to first selectors, to test each outlet for the engaged condition, and to switch through the call when a free selector is found. Similarly, a group selector, after being stepped to the required level under the control of dial impulses, must automatically hunt over the contacts of that level to find and switch to the first available trunk to the next switching stage. Somewhat different conditions obtain on circuits such as a linefinder where the selector is required to search for a particular marked contact and to switch only when this marked contact is found. The two processes may be aptly described as *hunting* and *finding* respectively. The circuits, by means of which automatic search is obtained, are substantially the same whether a selector is required to "hunt" for the first free outlet or, alternatively, to "find" a particular marked contact.

The main requirements of an automatic drive circuit are a high speed of search coupled with reliability of operation. In this connexion it should be remembered that in most circumstances the time available to hunt for, find and seize a free trunk is limited to the period between successive impulse trains, i.e. to the minimum interdigit pause of some 400 msec. This limitation does not apply to subscribers' uniselectors or linefinders but, even so, the maximum speed of search is desirable in order to minimize the time necessary to return dial tone to the caller.

The testing circuit of a selector is required to differentiate between outlets which are engaged and those which are free and available for use. During automatic search, the time for which the wipers of a selector rest on any one contact is comparatively small. During this very limited period the testing circuit must discriminate and, if the outlet is free, must stop the drive of the selector. Apart from this requirement, consideration must also be given to the possibility of several selectors testing the same outlet more or less at the same instant. A good testing circuit will minimize the possibility of "double connexions" due to the simultaneous testing and switching of two searching selectors.

The actual process of switching to a chosen outlet may or may not be combined with the process of testing. In some cases the testing relay itself carries out the switching operation whilst in others the actual switching is indirectly controlled by the operation, non-operation or release of a separate testing relay. Generally the testing and switching circuits are so closely associated that they must be considered together as one operation. Automatic drive circuits are also closely linked with the testing and switching circuits, and it is convenient to consider the three problems together in this chapter.

Self-drive Circuits. The method employed for causing a mechanism to search automatically over the available outlets accounts to a large extent for the differences in various automatic systems. In some instances (e.g. Western Electric Rotary System) the selecting wipers are rotated by means of motor-driven shafts, the selector being coupled to the drive system by electromagnetic clutches. In other systems (e.g. Siemens No. 16 System) automatic search is obtained by a ratchet and pawl drive controlled by an electromagnet supplied with machine generated impulses. In the standard Post Office system automatic search is obtained in nearly all cases by interrupting the driving magnet current either directly or indirectly from contacts associated with the driving magnet armature. This method of interacting the driving magnet and its associated contacts is commonly known as a *self-drive* circuit, to distinguish from other systems where the drive is dependent upon an external source.

A simple form of self-drive circuit is shown in Fig. 249. *DM* is, as usual, the selector driving magnet, whilst contacts *dm* are mechanically coupled to the driving magnet armature in such a way that the contacts open when the armature is attracted. When hunting is required, contact ***B*1** closes and completes the circuit for the mechanism driving magnet via the interrupter contacts *dm*. The driving magnet attracts its armature and, at a late point in the stroke, contacts *dm* break and so disconnect the magnet circuit. The armature now releases and eventually the *dm* springs remake during the return movement of the armature. The magnet is now re-energized and the process continues until the drive circuit is broken, i.e. until a free outlet is found or the call is abandoned.

It should be noted that with the simple self-operated drive circuit of Fig. 249 it is desirable that, to ensure full operation of the armature, the

interrupter springs should open as late as possible in the armature stroke. It is equally desirable from the point of view of ensuring full release that the

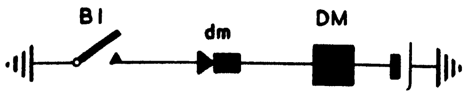


FIG. 249. ELEMENTARY SELF-DRIVE CIRCUIT

springs should not again close and remake the magnet circuit until the armature is fully released. With interrupter springs of the usual mechanical design these two requirements are incompatible. The adjustment must in practice be a compromise and very careful attention to design is required to obtain satisfactory and reliable operation. The self-interrupted drive circuit illustrated in Fig. 249 is in essence that of an ordinary trembler bell but with the difference that the moving system is of much greater mass and hence has a correspondingly greater momentum at the time the circuit is broken. By taking advantage of the momentum of the moving system at the time of break, it is usually possible to provide an interrupter contact adjustment which will give the required range of armature movement to operate the ratchet and pawl system. Nevertheless, in some circumstances, the adjustment is critical and there is always the tendency for the circuit to act as a "buzzer."

Apart from this aspect, there are other considerations in the design of a self-drive circuit which must be considered. In the first place it is necessary to ensure that the interrupter contact adjustment allows sufficient tolerance to cater for ordinary maintenance requirements. In addition, it is usually necessary to obtain the maximum possible hunting speed consistent with reliable stepping whilst, thirdly, the drive circuit must be considered in conjunction with the testing circuit.

Self-drive with Reverse-acting Mechanisms. Fig. 250 shows diagrammatically the operation of a reverse-acting mechanism under self-drive conditions. The upper part of the illustration gives the approximate waveform of the current in the selector driving magnet, whilst the period for which the interrupter contacts are closed is shown below. The lower part of the diagram illustrates the armature movement and the time for which the wipers rest on the bank contacts throughout the cycle of operations.

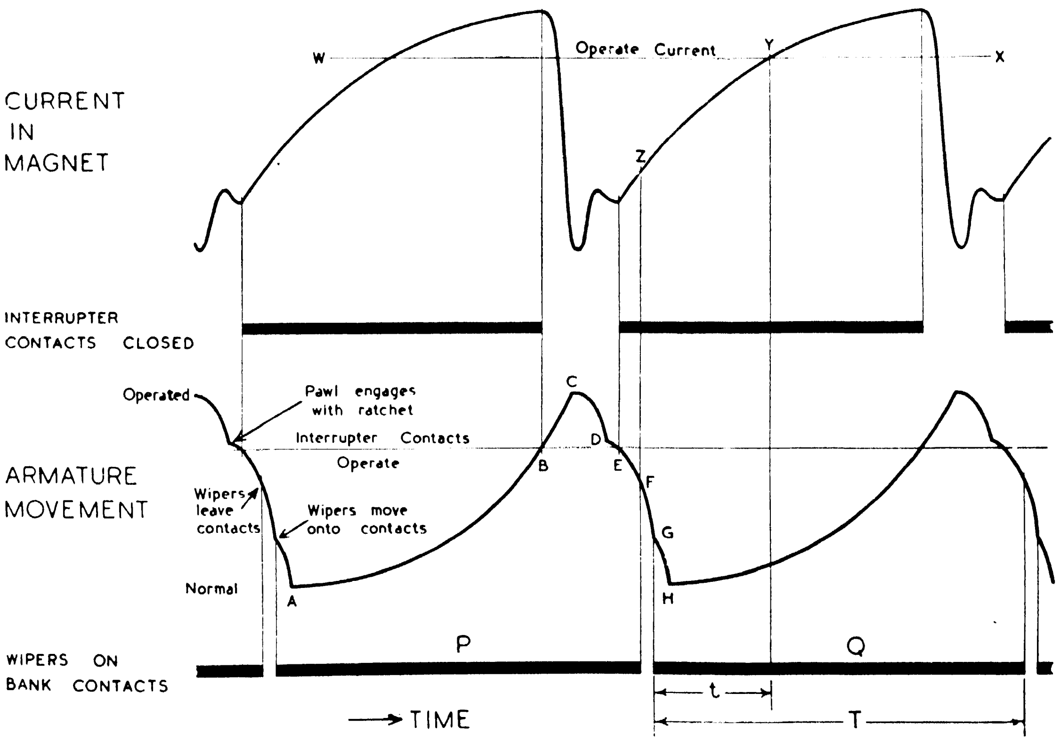


FIG. 250. OPERATION OF REVERSE-ACTING MECHANISM UNDER SELF-DRIVE CONDITIONS

When the drive circuit is closed, the current commences to rise in the magnet winding and the armature gradually accelerates from rest and moves at an ever-increasing speed until its progress is suddenly arrested by the armature front stop. The acceleration of the armature on the forward stroke is shown by the curve ABC. At point B during the forward movement of the armature, the interrupter contacts open and the current in the magnet is disconnected. The design is such, however, that the momentum of the moving system carries forward the armature from B to C in spite of the disconnexion of the circuit.

During the reverse movement, the armature starts from rest at C and again accelerates until point D is reached. At this point the pawl engages with the ratchet and there is a momentary fall in speed due to the sudden additional load. As the armature again accelerates, the interrupter contacts reclose at point E, whilst at point F the wipers leave one set of bank contacts. At point G the wipers engage with the next set of bank contacts and again there is a slight interruption of the acceleration curve due to the additional load. Finally, the armature comes to rest in its normal position at point H.

It will be noted that, with a reverse-acting mechanism, the load on the armature is a minimum when the latter commences to move from normal and gradually builds up due to the increasing tension of the restoring springs until the maximum load is reached when the armature is fully operated (i.e. point C). On the other hand, substantially the maximum restoring spring tension is available when the pawl engages with the ratchet wheel (i.e. point D). It is at this point that the frictional resistance is greatest, and once the wiper assembly commences to move, then the gradually decreasing tension of the restoring spring will maintain the movement against the lower resistance as the moving system accelerates. In a forward-acting mechanism, the maximum load is encountered early in the forward movement of the armature at a time when the tractive force is low due to the slow rise of current in the magnet windings. Under comparable conditions the time taken for the forward stroke of a reverse-acting mechanism is usually appreciably less than the time for a similar movement on a mechanism of the forward-acting type. It is true that the armature of a forward-acting mechanism will release somewhat quicker than that of a reverse-acting switch, but the difference is not very great owing to the large restoring force available in the reverse-acting mechanism at the moment when the wiper assembly commences to move. For these reasons reverse-acting mechanisms usually have a higher hunting speed under self-drive conditions than similar mechanisms of the forward-acting type.

The interrupter contacts of a reverse-acting mechanism must be adjusted to break sufficiently late to enable the pawl to slip over the next tooth of the ratchet wheel. On the other hand, if the interrupter contacts are adjusted to break very late in the forward stroke of the armature they will re-make correspondingly early on the return stroke. It is desirable that the total period for which the contacts are open should be sufficient to allow the magnet current (and flux) to fall substantially to zero before the magnet circuit is again completed. If this period is too short, then there is inadequate time for the flux to decay to a value which will allow of full release of the armature. In these circumstances there is a danger that the armature will merely buzz instead of stepping the wiper assembly. In practice, the interrupter contacts are adjusted so that they break just before the pawl drops into the ratchet tooth.

Since the wiper assembly is not moved during the forward motion of the armature, it is possible to design a switch so that the armature continues to move forward for a time after the pawl has engaged with the ratchet tooth. By arranging that the movement of the pawl is, say, 33 per cent greater than the pitch of the ratchet teeth, it is possible to take advantage of the momentum of the moving system and so to increase the time for which the interrupter contacts are open. In practice it is not difficult to design a reverse-acting mechanism which will give a high speed of stepping during self-drive and which does not involve critical adjustment of the interrupter contacts.

It is interesting to compare, in Fig. 250, the current in the magnet with the time for which the wipers rest on successive bank contacts. It has been seen that during the return stroke of the armature the wipers leave one set of bank contacts at point F and engage with the next set of contacts at point G. The total period for which the wipers rest on any one bank contact is shown by distance T. It has also been seen that the interrupter contacts re-close at point E. At this point the current commences to rise in the magnet coil at a rate depending upon the time constant of the circuit. To allow of a working tolerance, the minimum current on which the mechanism will operate is somewhat less than the peak current obtained under working conditions. If it is assumed that this minimum operate current is WX, then the time EY will elapse before the current rises to the operate value. If the current should reach this operate value, then the mechanism will make a

further step—irrespective of the electrical condition on the bank contacts. It is clear, therefore, that when mechanisms of the reverse-acting type are used, the testing circuit must be capable of disconnecting the drive circuit (if the outlet is free) within a period "t" from the time when the wipers first reach the bank contacts. Thus, although the period for which the wipers are standing on any one bank contact may be T, the associated circuit driving circuit as the wipers pass from contact to contact. It should also be noted that when the wipers pass from an earthed bank contact to a free contact without earth, the highly inductive magnet circuit is broken by the wipers and not by the interrupter contacts. With a reverse-acting mechanism this is not of serious consequence, since at the point where the wipers leave the bank contact, the current in the magnet is just commencing to rise

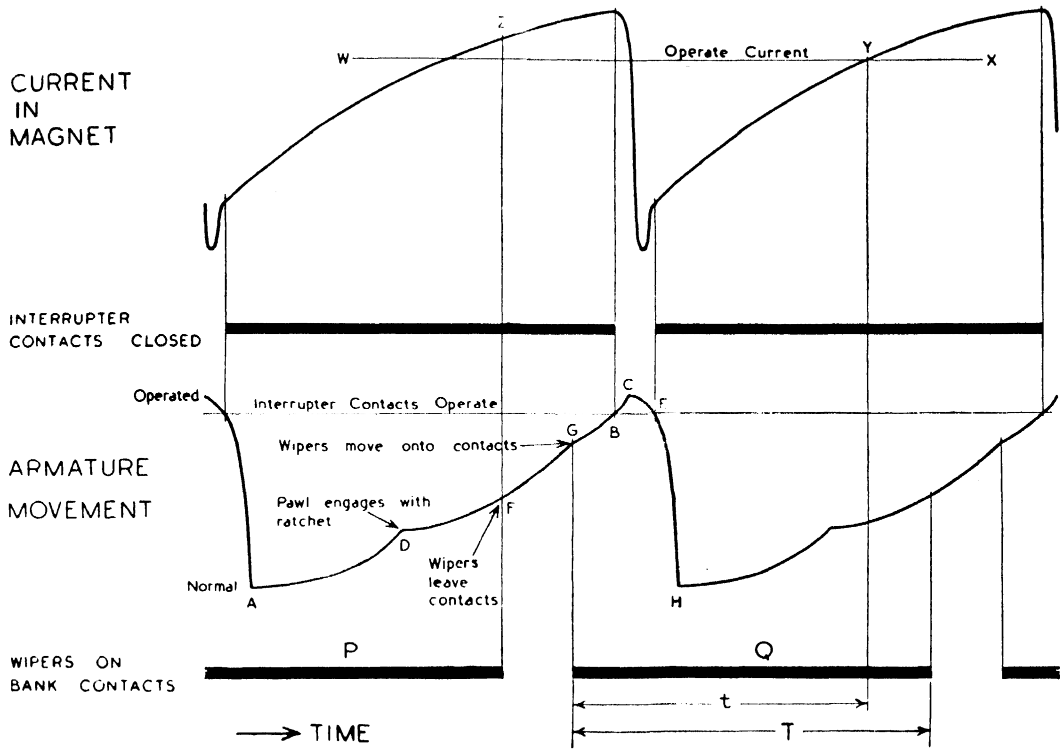


FIG. 251. OPERATION OF FORWARD-ACTING MECHANISM UNDER SELF-DRIVE CONDITIONS

must be capable of discriminating within a much shorter period t.

This characteristic of reverse-acting switches renders them somewhat prone, under certain conditions, to "overstepping." The danger of overstepping is in practice often eliminated by arranging that the magnet circuit is completed through the wipers and bank contacts. Assume, for example, that in Fig. 250 the driving magnet circuit is completed via its interrupter contacts and the selector wipers to an earth on bank contact P. If there is no earth on bank contact Q, then the current cannot possibly rise beyond value Z, irrespective of the time taken to test contact Q. This system does, as will be seen later, necessitate the use of bridging wipers, in order to maintain continuity of the and there is very little inductive energy stored in the system. If the magnet current were appreciable at the time of disconnexion, it would result in serious arcing and rapid deterioration of the wipers (and possibly of the bank).

Self-drive with Forward-acting Mechanisms. The operating characteristics of a forward-acting mechanism under self-drive conditions are shown in Fig. 251. The curves and reference letters have the same significance as for the reverse-acting type of switch. In this case, the armature moves from rest at point A and gradually accelerates up to point D when the pawl engages with the ratchet. The maximum load is encountered at this point at a time when the tractive force is comparatively small due to the slow build-up of the current in the

magnet coil. There is usually a sudden decrease in velocity until the increasing tractive force of the magnet gradually accelerates the moving system. There is a further slight decrease in the acceleration at point G when the wipers move on to the next set of bank contacts. The armature finally completes its forward movement at point C and then rapidly accelerates in a reverse direction until it finally restores to normal at point H. A comparison of Figs. 250 and 251 shows clearly why forward-acting mechanisms are usually slower under self-drive than similar reverse-acting switches.

With mechanisms of the forward-acting type, the wipers are rotated during the forward movement of the armature. It is therefore not practicable to allow the armature to move forward beyond the

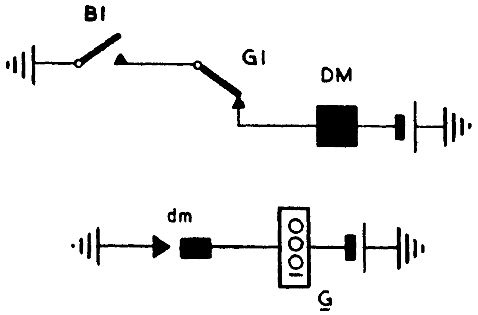


FIG. 252. SELF-DRIVE CIRCUIT WITH INTERACTING RELAY

point where the wipers are located centrally on the bank contacts. Any attempt to allow the armature to over-ride, as in the reverse-acting switch, would result in undesirable "backlash" and at the worst would cause the wipers to step off the bank contacts. In practice, a forward-acting mechanism is adjusted so that the wiper retaining pawl just engages with a ratchet tooth when the armature is fully operated. This characteristic necessitates a very late break of the interrupter contacts which in turn results in a comparatively short period of contact opening during which the magnet flux is required to decay. There is therefore a very much greater tendency for the armature to "buzz" on forward-acting mechanisms, and, if the simple self-drive circuit of Fig. 249 is applied, say, to the rotary magnet of a 2-motion selector, the interrupter contact adjustments become very critical.

A further comparison of Figs. 250 and 251 shows that there is little danger of overstepping on switches of the forward-acting type. If the driving magnet operating current is, as before, WX, then the time "t," during which the testing circuit must discriminate and, if necessary, disconnect the driving magnet circuit, is substantially greater than with the reverse-acting mechanism. The time available for testing is in fact very little less than the time T for which the wipers stand on the contact. It will be noted that it is not practicable to complete a self-drive circuit through the wipers and bank contacts as in the case of the reverse-acting mechanism. The wipers leave bank contact P at point F and at this time the current in the magnet is shown by point Z. Apart from the impracticability of disconnecting a highly inductive circuit which is carrying substantially the full current, there is a very grave danger that the drive circuit might be disconnected before the current has risen to the operate value. If this should happen, the retaining pawl would not engage with the next tooth of the ratchet wheel and the wipers would fall back to the previous contact.

Self-drive with Interacting Relay. It has been seen that the elementary self-drive circuit illustrated in Fig. 249 involves critical adjustment of the interrupter contacts when it is applied to mechanisms of the forward-acting type. Whilst the circuit has been retained for subscribers' uniselectors (reverse-acting), this elementary circuit was abandoned for the rotary drive of 2-motion selectors some years ago. The more recent circuits of pre-2000 type 2-motion selectors utilize the circuit arrangement of Fig. 252. As before, contact ***B*1** completes the driving magnet circuit but the *dm* springs (which are now of the make type) close the circuit for relay G. ***G*1** in turn breaks the driving magnet circuit and, when the armature releases, the *dm* springs reopen to release relay G. The circuit for the driving magnet is again completed at $G1$ and the process continues for so long as ***B*1** is closed.

With this arrangement the driving magnet current is maintained after the closure of the *dm* springs for a period equal to the operating lag of G. Similarly, on release, the re-energization of the driving magnet is delayed for a period determined by the release lag of G. Thus the stepping can be fully controlled by the adjustment of the *dm* springs and the operate and release lags of G. The inclusion of the G relay operate and release lags has the same effect as mechanical interrupter springs which are arranged to break very late in the forward stroke of the armature and to re-make late during the return movement of the armature.

Toggle Interrupters. Although the circuit of Fig. 252 gives reliable stepping and avoids critical adjustment of the *dm* springs, it gives a comparatively low speed of drive due to the difficulty of designing a G relay with sufficiently fast operate and release times. The circuit does, moreover, involve the use of an additional relay—although it is

usual to arrange for the G relay to have certain other functions in addition to that of controlling the automatic drive circuit. In 2000 type selector circuits there has been a reversion to the simple self-drive circuit of Fig. 249 in order to save the additional relay and to obtain higher hunting speeds. Critical adjustment of the interrupter contacts has been overcome by the use of an ingenious toggle action.* By this mechanical arrangement it has been possible to obtain the desired late break on the operation of the armature and the opposing requirement of a late re-make on release. The principle of the toggle interrupter is illustrated in Fig. 253. The interrupter contacts are directly controlled by the toggle, which is fitted with a bias spring so that when it is moved to the operated position it remains until it is mechanically restored by the return movement of the armature. The latter is fitted with a U-shaped extension, so proportioned that the toggle is operated late in the forward stroke of the armature and is restored late in the return stroke. Fig. 254 shows the arrangement in its practical form and should be compared with the illustration of the toggle interrupter given in Chapter III.

The Private-wire. It has already been stated that in an automatic exchange a third wire (in addition to the speaking pair) is required to control the setting up and holding of a connexion and to provide facilities for the testing of outlets, for the metering of calls, etc. The third wire is known as the private-wire (or perhaps more generally as the P-wire), and it is the electrical *potential* on the P-wire which determines whether or not any particular outlet is free or engaged. In general, an earth potential on the P-wire of any subscriber's line, selector or selector outlet indicates that the line, selector or outlet is engaged. Conversely, a

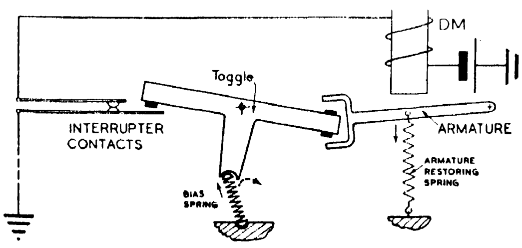


FIG. 253. PRINCIPLE OF TOGGLE INTERRUPTER

battery potential is often adopted to indicate that a selector or line is free. No potential (i.e. a disconnexion) on the P-wire of a circuit is sometimes chosen for the free indication, although it is rarely used to indicate specifically the engaged condition.

* British Patent 433877.

As will be seen later, however, certain testing circuits will test a disconnexion on the P-wire as an engaged outlet, whilst other testing circuits will switch to such an outlet as a free trunk.

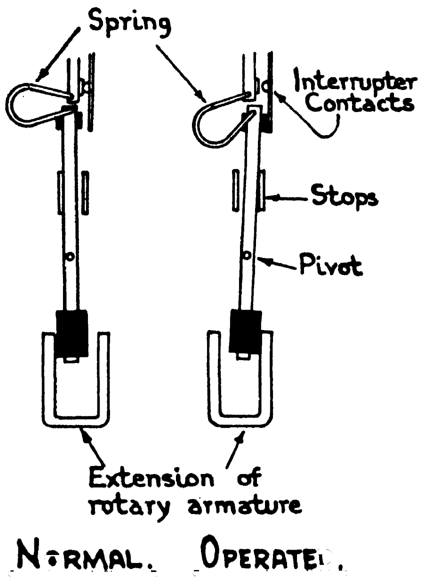


FIG. 254. PRACTICAL FORM OF TOGGLE INTERRUPTER

Testing Circuits. There are numerous designs of testing circuit employed in automatic selector circuits, but generally speaking all testing circuits may be classified under the following two types:

(*a*) *Battery testing circuits* in which switching will take place only if a battery potential is encountered on the P-wire, any other condition (earth or disconnexion) being regarded as engaged.

(*b*) *Earth testing circuits* in which an outlet is considered engaged only if there is an earth on the P-wire. An earth testing circuit will therefore switch either to a battery or to a disconnexion on the P-wire.

Both systems are used in modern automatic switching circuits but, as will be seen later, battery testing is generally preferable in circumstances where there is a high probability of two circuits testing the same outlet more or less simultaneously. Battery testing has also some advantages in preventing the re-seizure of a mechanism before it has fully restored to normal from a previous call.

Earth Testing Circuits. There are three fundamental principles upon which earth testing circuits can be designed. The simplest and possibly the most common scheme is to arrange that an earth potential on the P wiper prevents the operation of the switching relay, whilst, when a free outlet

is found, the absence of such an earth allows the switching relay to operate. Apart from its simplicity, the particular merit of this method is that the testing relay can also be used as the switching relay.

As an alternative, an earth testing circuit can be designed so that the testing relay operates at each step if earth is encountered on the *P* wiper but does not operate when a free outlet (with no earth potential) is encountered. This method involves the provision of a separate switching relay which

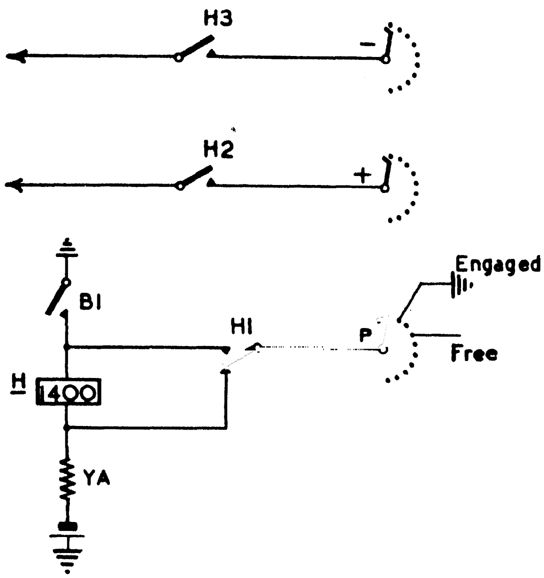


FIG. 255. EARTH TESTING CIRCUIT WITH BRIDGING *P* WIPER

is energized only when the test relay fails to operate. With this method the hunting speed is dependent upon the operate and release lags of the testing relay and hence the method is more appropriate to drive circuits with a low speed of search. It is particularly applicable to circuits which employ the interacting type of self-drive circuit (Fig. 252) where the stepping relay (*G*) can also be utilized as a testing relay.

The third alternative principle is to arrange that the testing relay is held for so long as earth potential is encountered on the *P* wiper, but when a free outlet is found the absence of earth allows the testing relay to release. This circuit again requires a separate switching relay but, as will be seen later, it has some advantages in minimizing the danger of double connexions and it is of particular value in high speed drive circuits.

Earth Testing Circuit with Bridging *P* Wiper. Fig. 255 shows a simple form of earth testing circuit for use in circumstances where the private wiper of the selector is designed to bridge adjacent contacts when passing from outlet to outlet. Such conditions are obtainable with the standard uniselector and in some of the earlier designs of 2-motion selector. With this scheme the engaged condition is a full earth on the *P* bank contact, whilst disengaged outlets are either disconnected or may have battery potential applied to them. When testing commences, contact ***B*1** closes but, for so long as the *P* wiper encounters earth conditions, the *H* relay cannot operate due to the presence of earth on both sides of the coil. When a free outlet is found, the absence of earth on the *P* bank allows relay *H* to operate from battery via the protective resistor *YA* to earth at ***B*1**. ***H*1** now disconnects the testing circuit and extends the earth from ***B*1** to guard and engage the seized outlet. Contacts ***H*2** and ***H*3** switch through the speaking pair. (The negative and positive wipers must, of course, be disconnected during search to prevent interference with established conversations.)

It will be appreciated that this testing circuit relies upon the continuity of earth potential on the *P* wiper as the mechanism passes over engaged outlets. If the adjustment of the *P* wiper is such that it leaves one engaged outlet before it connects with the next earthed contact, then the removal of earth from the battery side of relay *H* is liable to result in the premature operation of the relay. Resistor *YA* is provided primarily to prevent the blowing of the fuse during the search over engaged outlets, but it should be of sufficient magnitude to limit the current so that no undue arcing occurs when the *P* wiper leaves an engaged outlet and passes to a free trunk.

Automatic Hunting with Earth Testing. Fig. 256 shows the development of the simple earth testing circuit described above to provide for automatic search over engaged outlets and to switch the call only when a free trunk has been found. It will be noted that the selector driving magnet with its interrupter springs (*dm*) in series have been inserted in the position previously occupied by the protective resistor (*YA*). The driving magnet is energized from the earths encountered on the *P* bank contacts and hence this element can be utilized only where the mechanism is of the reverse-acting type (see Fig. 250).

When earth is encountered on the *P* bank, the magnet is energized to this earth via *H*1 and *dm*. Towards the end of the forward stroke of the armature, the interrupter springs (*dm*) break, and the disconnexion of the magnet circuit allows the mechanism restoring springs to move the wipers to the next bank contact. If earth is again

encountered on this outlet, the driving magnet (*DM*) is again energized and stepping proceeds until the *P* wiper moves on to a bank contact where there is no earth potential. There is now no circuit for the driving magnet, and the absence of earth allows relay *H* to operate in series with it. Due to the high resistance of relay *H*, the current is, of course, insufficient to operate the driving magnet. Contact ***H*1** extends guarding earth to the seized outlet whilst ***H*2** and ***H*3** switch through the call to the next stage.

The connexion shown by the broken line in Fig. 256 is used (when required) to provide an initial drive circuit for the selector magnet if the contact on which the wipers normally rest is not used as a working outlet. The earth from ***B*1** is extended via the broken line connexion to the home contact and thence via the *P* wiper to energize the driving magnet and so to step the wipers from the home position.

Earth Testing Circuit for Use with Non-bridging *P* Wiper. The circuits of Figs. 255 and 256 rely upon the fact that the *P* wiper bridges adjacent contacts as it passes from outlet to outlet. This bridging is essential in order to maintain the short-circuit across the switching relay (*H*). The wipers

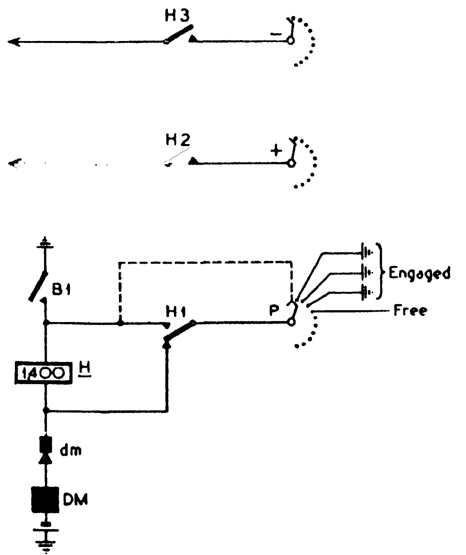


Fig. 256. Combined Self-drive and Earth Testing Circuit

of all modern 2-motion selectors are of the non-bridging type and a modified circuit is therefore necessary, under such circumstances, to prevent the operation of relay *H* as the wipers pass from one contact to the next.

Fig. 257 shows a typical circuit arrangement. It is substantially similar to the principle illustrated in Fig. 255, except that the battery is applied to the *H* relay only whilst the rotary make contacts

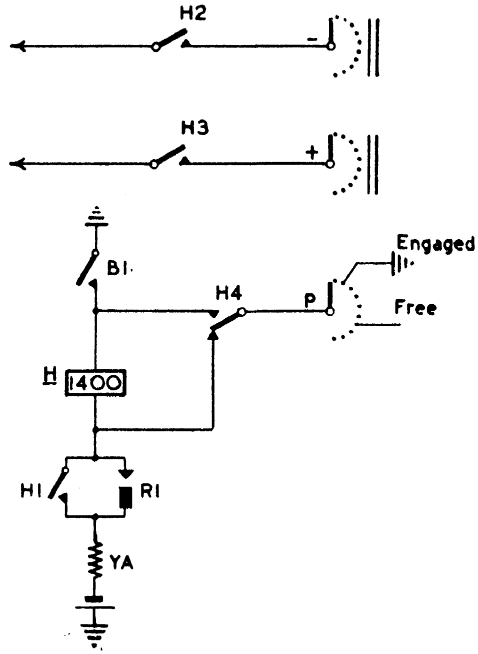


Fig. 257. Earth Testing Circuit for Use with Non-bridging *P* Wiper

(***R*1**) are operated. The adjustment of these contacts is such that they are closed only whilst the wipers are standing on bank contacts and are broken during the time when the wipers are moving from one contact to the next. When the *P* wiper is moving from an engaged outlet, the battery supply to the *H* relay circuit is disconnected at R1 before the earth is removed from the lower side of relay *H* due to the wiper leaving the contact. When the wipers step on to a free outlet, contacts ***R*1** operate, and the absence of an earth on the *P*-wire allows relay *H* to operate to the earth at ***B*1**. ***H*1** now provides a holding circuit for *H* in readiness for the release of the rotary make contacts.

Combined Earth Testing and Rotary Hunting (Non-bridging *P* Wiper). Fig. 258 shows a combination of the earth testing circuit of Fig. 257 and the interacting relay type of rotary drive circuit illustrated in Fig. 252. The combined element has been used extensively on circuits such as group selectors of the pre-2000 type.

At the end of the impulse train, relay *C* releases (see Chapter V), and at *C*1 completes the rotary magnet circuit. The energization of the rotary magnet steps the wipers into the bank, and

towards the end of the armature stroke the rotary make contacts **R1** close. The 210 Ω winding of G is now applied to the P wiper via **B2** and $H1$. If

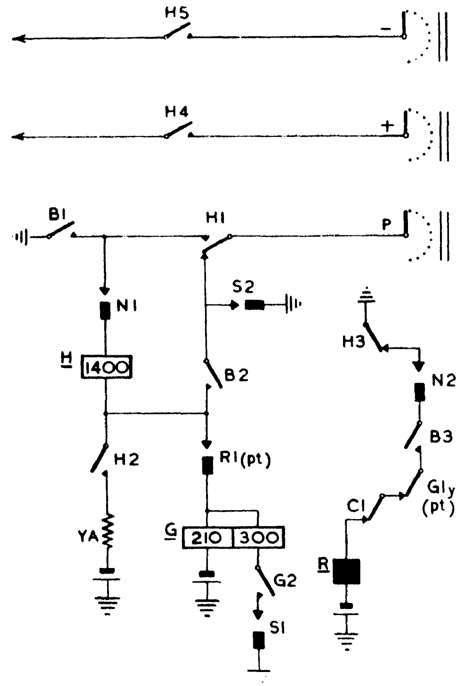


FIG. 258. EARTH TESTING WITH INTERACTING RELAY DRIVE CIRCUIT

the first outlet is engaged, the earth on the P-wire maintains the short circuit on H and also operates G. The operation of G now breaks the rotary magnet circuit at **G1**, and the armature releases. $R1$ in turn disconnects G, and the rotary magnet is re-energized to step the wipers to the next outlet. This interaction continues until a free trunk is found, when the absence of earth on the P-wire allows H to operate in series with G. ***H*3** breaks the rotary magnet circuit, ***H*2** provides a locking circuit for H, whilst the remaining contacts of relay H switch the call through to the succeeding stage.

If all outlets on the particular level are engaged, the wipers are stepped to the 11th rotary position, and the 11th step cam springs ***S*1** and ***S*2** are operated. ***S*2** allows G to operate and prevents the operation of H. ***G*1** disconnects the rotary magnet circuit, but ***S*1** now holds relay G over its two windings in series until the call is abandoned. As will be seen later, other S contacts in conjunction with contacts of the G relay return busy tone and flash to the calling party. It will be noted that the $R1$ and $G1$ contacts, which control the G relay and rotary magnet circuits respectively during rotary hunting, are of platinum on account of the comparatively heavy currents involved.

Earth Testing with Pre-operated Testing Relay. In circuits of the type illustrated in Fig. 258, the drive is dependent upon the conditions encountered by the P wiper. When a free outlet is found, the drive control relay (G) fails to operate, and the drive is immediately arrested. There is no time limit to the operation of the switching relay, and this relay can, if necessary, be very heavily loaded.

If a high speed self-interrupted drive circuit (Fig. 249) is required, the absence of a drive control relay makes it difficult to arrange the circuit so that the drive is arrested by the conditions encountered by the P wiper. With such a drive, reliance must be placed upon the testing circuit responding quickly to the condition on the P wiper, and, if the outlet is free, contacts of the testing relay must cut the independent self-drive circuit. If the testing relay also carries out the switching functions, it is usually necessary to provide a large number of contact springs. This heavy loading in

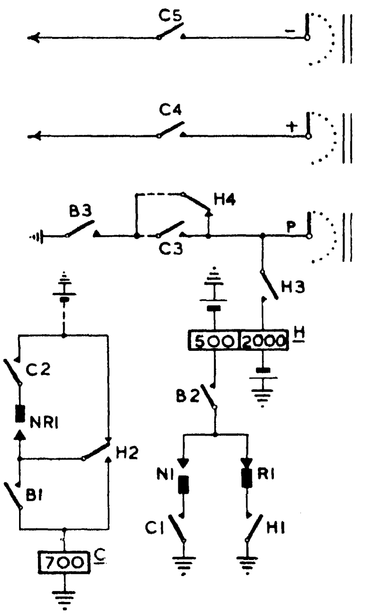


FIG. 259. USE OF PRE-OPERATED TESTING RELAY

turn necessitates a large number of ampere-turns on the relay, and the load, together with the high inductance of the relay, makes it difficult to ensure reliable operation during the short time for whic the switching relay is applied to the P-wire. Th time of operation can be reduced to some exte

by providing a lightly-loaded quick-operating testing relay and a relief relay to carry out the main switching operations. Apart from the cost of the two relays, the space required is an important consideration.

An alternative method, and the one adopted in 2000 type group selector circuits, is to arrange that the testing relay is operated when the circuit is seized but *releases* when a free outlet is found. It is readily possible to design a relay of the ordinary telephone type to give a release lag of less than 5 msec, whereas it would be necessary to provide a special high-speed relay if the circuit conditions required the relay to operate within so short a period. The short response time of the pre-operated testing circuit has also some material advantages in respect of double switching (see later paragraphs). This method does, of course, require the use of a second relay which can be operated by the release of the testing relay to carry out the switching operation. In most circumstances, however, it is possible to utilize some other relay in the circuit (usually *C*) as a switching relay in addition to its normal function.

Fig. 259 illustrates the principle of a testing circuit with a pre-operated relay. Relay *H* is operated on its 500 Ω coil via **C1** and **N1** when the switch commences its vertical stepping. Relay *C* releases at the end of the vertical train, but *H* is held under the control of the rotary interrupter contacts *R*1. At each step the **R1** contacts open when the wipers are firmly established on the bank contacts. If the outlet is busy, an alternative holding circuit is provided by the 2000 Ω winding of *H* via **H3** to the earth on the *P* wiper. If the outlet is free, there is no holding circuit for *H* which releases during the open period of contacts **R1**. When the *R*1 contacts reclose, *H*1 now prevents the re-establishment of the 500 Ω coil circuit, whilst *H*3 disconnects the 2000 Ω coil from the *P*-wire. *H*4 applies a temporary engaging earth to the seized outlet.

*H*2 allows *C* to re-operate and lock to contact **C2**, whilst **C3**, **C4** and **C5** switch through the lines. **C1** re-operates *H* which remains held via **H3** to the earth on the *P*-wire for the duration of the call. If the call is to be held from some other selector, the final operation of *H* allows the *B* relay to release, thereby placing the holding circuit for the *C* relay under the control of contact **H2**. At the end of the call, relay *H* releases due to the removal of the earth from the *P*-wire and in turn releases *C* to restore the circuit to normal.

The sequence of operations is somewhat more complex than in the testing circuits previously considered, but the circuit operation can readily be memorized if the following basic requirements are recalled:

(*a*) Relay *H* is pre-operated prior to the commencement of hunting in order that it shall be available to release when the first free outlet is encountered.

(*b*) Relay *C* is released at the commencement of rotary hunting after fulfilling its function in the impulsing circuit.

(*c*) The release of *H* when a free outlet is found

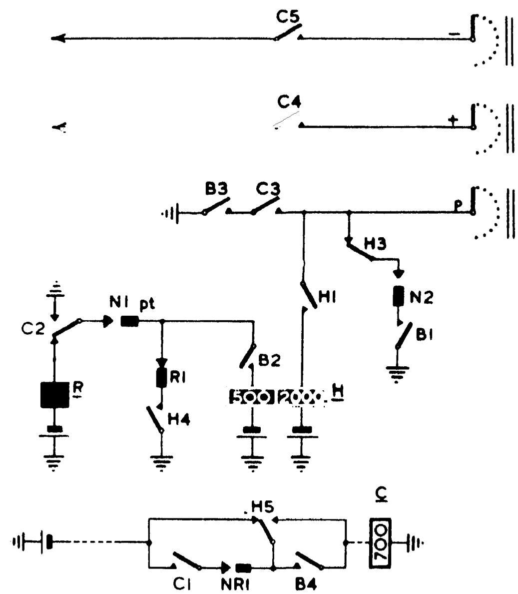


FIG. 260. ROTARY HUNTING WITH PRE-OPERATED TESTING RELAY

allows *C* to re-operate and to complete the switching of the call.

(*d*) The re-operation of *C* allows *H* to re-operate and hold to the earth on the *P*-wire. The removal of this earth at the termination of the call allows *H* to release, and *H* in turn releases *C* and allows the selector to restore to normal.

Rotary Hunting with Pre-operated Testing Relay. Fig. 260 shows a complete hunting and testing element utilizing the principle of a pre-operated testing relay. When the circuit is seized, the *B* relay is operated and contacts **B1**, **B2**, **B3**, and **B4** are closed. The latter contact operates relay *C* which is then held until the end of vertical stepping. At the first vertical step, the **N1** contacts close and the *H* relay is operated on its 500 Ω coil to the earth at **C2**. **H4** now provides a holding circuit for *H* independent of the **C2** contact but under the control of the *R*1 contacts. At the end of the vertical impulse train, *C* releases (due to the cessation

of current pulses in its low resistance coil—see Chapter V) and at $C2$ completes the circuit for the rotary magnet from the earth at **$H4$** via $R1$, **$N1$**, and $C2$. The wipers are now rotated under self-interrupted drive until such time as the circuit is broken by the release of $H4$.

P-wire. The release of $H5$ allows C to re-operate and lock to its own contact **$C1$**. Contacts **$C3$**, **$C4$**, and **$C5$** complete the switching operation, whilst **$C2$** re-operates relay H. H now holds to the earth on the P-wire for the duration of the call and by releasing relay B places the holding

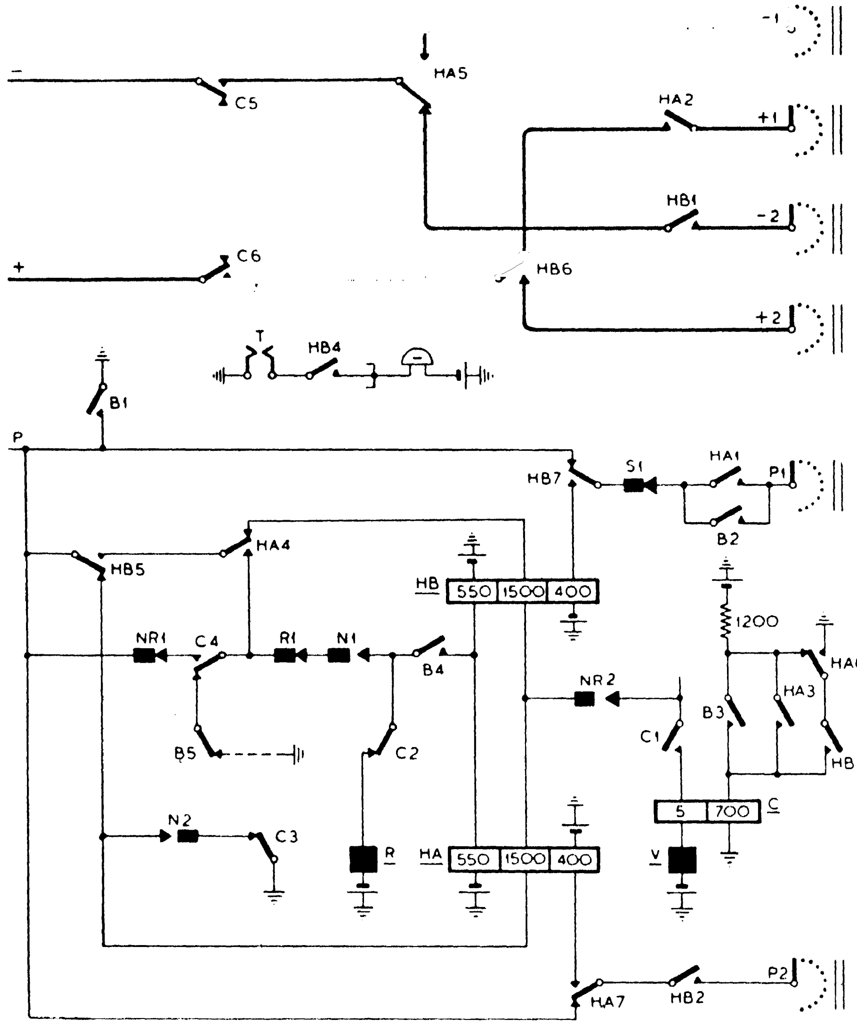


FIG. 261. ROTARY HUNTING WITH DUAL TESTING

At each rotary step, the holding circuit for relay H is broken by the opening of the **$R1$** contacts, but if the outlet is engaged an alternative holding circuit is provided through the 2000 Ω coil from the earth on the P-wire via **$H1$**. When a free outlet is encountered, the absence of earth allows H to release during the open period of **$R1$**, and the restoration of $H4$ disconnects the rotary drive circuit whilst $H3$ provides a temporary earth to the circuit for relay C under the control of the **$H5$** contact.

Rotary Hunting with Dual Testing. The principle of testing two outlets concurrently to obtain an availability of 20 on each level of group selectors has been explained in Chapter II. Fig. 261 shows a development of the rotary hunting circuit with pre-operated testing relay (Fig. 260) to provide dual testing on 200-outlet group selectors.

The two switching relays are designated *HA* and *HB*, and the circuit is so arranged that, if both outlets are free, precedence is given to the *P*1 bank.

When the selector is seized, the *B* and *C* relays are operated, and at the first vertical step the closure of the off-normal springs allows relays *HA* and *HB* to operate via ***B*4**, ***N*1**, *R*1, ***C*4**, and *NR*1 to the earth at ***B*1**. Contacts ***HA*4** and ***HB*5** provide an alternative holding circuit for the *HA* and *HB* relays independent of *NR*1 and ***C*4**. Contacts ***HA*6** and ***HB*3** short-circuit the 700 Ω winding of the *C* relay to shunt out the pre-operate circuit and to make the relay slow to release under the control of the dial impulses. ***HA*7** and ***HB*2** extend the 400 Ω coil of *HA* to the *P*2-wire in readiness for testing, whilst ***HA*1** and ***HB*7** similarly extend the same coil of relay *HB* to the *P*1-wire.

At the end of the vertical impulse train, relay *C* releases and at *C*1 disconnects the circuit of the vertical magnet. *C*2 now completes the rotary magnet circuit via ***N*1**, *R*1, ***HA*4**, ***HB*5**, and ***B*1**. The wipers are stepped into the bank and, when the rotary armature is almost fully operated, the ***R*1** contacts open, thereby disconnecting both the rotary magnet circuit and the holding circuit of relays *HA* and *HB*. If both outlets are engaged, relays *HA* and *HB* hold on their 400 Ω coils to the earth on the *P*2 and *P*1 wipers respectively. If, on the other hand, the *P*1 outlet is engaged but the *P*2 outlet is free, then relay *HA* releases but *HB* is held to the earth on the *P*1 wiper. The restoration of *HA*6 allows *C* to re-operate on its 700 Ω coil, and ***C*1** completes a holding circuit for relay *HB* on its 1500 Ω winding to the battery at the *V* magnet via ***C*1**, ***NR*2**, *HA*4, ***HB*5**, and ***B*1**. Contacts ***C*5**, ***C*6**, ***HB*1** and ***HB*6** switch the negative and positive lines to the even outlet, and in due course relay *B* releases to leave the call under the control of the earth on the *P*2-wire from a succeeding stage. During the call the *HB* relay is held on its 1500 Ω coil to the vertical magnet battery from the earth via *HA*4, ***HB*5**, *HA*7, ***HB*2** to the earth on the *P*2-wire, the 400 Ω coil of the *HB* relay being disconnected from the *P*1 wiper by the release of *B*2. At the end of the call, the removal of the earth on the *P*2 wiper releases *HB* which at *HB*3 disconnects the *C* relay to restore the switch to normal.

If the *P*1 outlet is free, but the *P*2 outlet is engaged, the *HB* relay releases and at *HB*3 removes the short circuit from the *C* relay which operates. Relay *HA* is held operated from battery at the *V* magnet via ***C*1**, ***NR*2**, *HB*5 to the earth at ***B*1**. ***HA*5** and ***HA*2** switch the call to the odd outlet. After the release of *B*, the *HA* relay remains held on its 1500 Ω coil via ***C*1**, ***NR*2**, *HB*5, *HB*7, *S*1, and ***HA*1** to the earth on the *P* wiper.

If the *P*1 and *P*2 outlets are free, relays *HA* and *HB* both release. *HB*3 in restoring removes the short circuit from the 700 Ω coil of relay *C* and allows it to re-operate, whilst *HB*5 prepares a re-operate circuit for *HA* on its 1500 Ω winding. When relay *C* operates, ***C*1** completes the circuit for *HA* whilst ***C*2** disconnects the rotary magnet to prevent further hunting. ***C*5** and ***C*6**, as before, switch through the lines. *HA* is now held for the duration of the call as described above.

With 200-outlet group selectors it is not possible to see, from a visual examination of the wipers and banks, the outlet to which switching has taken place. To facilitate the tracing of calls, a test trunk bell is provided per 200-outlet group selector rack. The bell is common to all group selectors on the rack, and a test jack (*T*) in each group selector is wired so that the insertion of a short-circuiting peg applies earth via contact ***HB*4** to the test trunk bell. If, therefore, the bell rings when a short-circuiting peg is placed in the appropriate test jack springs, it indicates that the selector has switched to the *P*2 outlet, i.e. to the upper group of banks.

Unguarded Periods. The switching relay of any earth testing circuit operates and holds over a local circuit, and hence it is difficult to guard against two selectors switching to the same outlet if both switching relays are fully fluxed before either applies a guarding earth to the *P*-wire. If in Fig. 258, for example, the operating lag of each relay in the exchange were, say, precisely 50 msec, it would theoretically be possible for two selectors to switch to the same outlet only if the *H* relays were applied to the free outlet at exactly the same instant—a very small probability.

Unfortunately, there must of necessity be variations of operate lag due to differing adjustments. More important is the fact that, although a relay normally takes, say, 50 msec from the time when the current commences to rise in the relay coil to the time of closure of the contact springs, it will nevertheless operate in practice if it is given a pulse of current of, say, 40 msec duration. The latter is often known as the *pulse operate time* to distinguish it from the normal *static operating lag* of the relay. It is apparent, therefore, that if the normal operate lag is 50 msec and the pulse operate lag is 40 msec there is a 10 msec unguarded period during which double connexions may occur.

In any particular circumstances the unguarded period is the difference between the maximum static operate lag of a relay in heavy adjustment and the minimum pulse operate lag of a relay

adjusted to the lightest permissible limits. An unguard period of 10 to 15 msec is common with the circuits of Figs. 255 to 258 due to the comparatively long operate lags of the heavily loaded switching relay. Circuits of the type illustrated in Fig. 260 (in which the switching relay releases at the time of testing) give a much lower unguarded period. This is due to the fact that both the normal and the pulse release lags are very much shorter than the equivalent operating lags of the earlier circuits. By the use of the pre-operated testing relay, therefore, it is possible to design earth testing circuits where the unguarded period on switching is reduced to some 1 or 2 msec.

An unguarded period also occurs with all earth testing circuits during release. It has been seen that the normal guarding condition is an earth on the *P*-wire. At the end of a call this earth must be removed for a short period to allow all the holding relays of the various selectors comprising the switching train to release. As will be seen later, it is possible to re-apply the guarding earth after the holding relays have been released until such time as each mechanism restores to normal. This method materially reduces the unguard period during release when it would be possible to seize a selector before it has fully restored from the previous call. Nevertheless, even when such guarded release circuits are employed, there is necessarily an unguarded interval between the initial removal of the earth from the *P*-wire and its re-application. This period is a fundamental requirement to allow the switching train to release and cannot be avoided in earth testing circuits of the type considered.

Battery Testing. The probability of service difficulties due to unguarded periods is dependent partly upon the length of the unguarded period and partly upon the nature of the traffic. For a given amount of traffic there is, for example, a much higher probability of simultaneous testing when the circuits are held for a short period than in circumstances where the traffic is made up of a smaller number of calls each with a higher average holding time. To illustrate, the probability of two circuits testing the same outlet simultaneously is ten times as great when the outlets are held for an average period of 18 sec as when compared with conditions when the average holding time is 3 min. The same considerations apply during release. It is therefore particularly important to minimize or to eliminate all unguarded periods when switching to common apparatus which is held only for a very short time.

The testing relay of a battery testing circuit operates to a battery potential encountered on the *P*-wire, but will not switch to an earth or a disconnexion. This characteristic of a battery testing circuit can be utilized to eliminate entirely the unguarded period during release. The circuit conditions can, for example, be arranged so that:

(*a*) The holding condition is an earth on the *P*-wire.

(*b*) The release condition is a disconnexion on the *P*-wire.

(*c*) The free condition (when the circuit is fully restored to normal) is a battery on the *P*-wire.

Moreover, in a battery testing circuit the operation of the testing relay is dependent upon the current received over the *P*-wire from the battery in the tested circuit, and in some cases the switching relay is also held by the current over the same circuit. It is therefore theoretically possible to arrange the current distribution so that, if two relays test the same outlet concurrently, there is insufficient current for both to operate. As an alternative, the circuit may be arranged so that, even if two testing relays both operate to the same free outlet, there will be insufficient current for both relays to hold. Apart from certain practical limitations which will appear later, a battery testing circuit can be made completely immune from double connexions, and hence battery testing circuits are now almost universally employed on circuits switching to common equipment where the holding time is short.

Battery testing has also a further advantage over earth testing. It will be seen from the earth testing circuits previously described that the guarding earth is applied to the *P*-wire by the testing circuit at the same time that the speaking pair is switched through to the seized outlet. In some circumstances it is desirable, or even essential, that a circuit should be prepared before the speaking pair is extended to it. For example, it is necessary to remove the line relay from the speaking pair of a subscriber's line circuit before the negative and positive wires are extended in order to avoid premature tripping of the automatic ringing circuit. In other circumstances, preliminary preparation of the circuit is desirable before the calling loop on the speaking pair is extended.

The fundamental condition for indicating a free outlet in a battery testing system is the presence of a battery on the *P* bank contact. For practical reasons a protective resistance must always be inserted in series with the battery, and when necessary this resistance can be replaced by a relay which will operate in series with the testing relay of the preceding stage. It is by this means possible to prepare a circuit coincident with the process of testing and before switching takes place.

Battery Testing Circuit with Local Holding Coil. A typical battery testing circuit which is used extensively in final selectors is illustrated in Fig. 262. At the termination of impulsing, relay C releases and at $C1$ applies earth to the 900 Ω operating coil of relay H. The other side of this coil is connected to the P wiper, and if the outlet on which the wiper stands is disengaged, the battery from the free line operates relay H. At the same time if there is a switching relay (K) in the circuit tested, it will also operate over this same circuit.

H1 provides a locking circuit for the H relay until the termination of the call, whilst ***H2*** applies full earth to the P-wire to engage it against any interference by other testing circuits. ***H3*** and ***H4*** switch through the speaking pair. It is desirable with this circuit that contact ***H1*** should close not later than contact ***H2*** in order to establish the holding circuit before the current is diverted from the operate coil. The short-circuiting of the 900 Ω coil by ***H2***, however, provides a sufficient release lag to guard against failure with all normal contact spring adjustments.

Marginal Operate Conditions to Prevent Dual Switching. With the battery testing circuit of Fig. 262 it is theoretically possible to prevent two H relays from switching to the same outlet. This can be obtained if the electrical constants of the circuit are such that, if two H relays test the same outlet simultaneously, there is insufficient current for either H relay to operate.

To be of the maximum value under normal working conditions, the circuit should be designed so

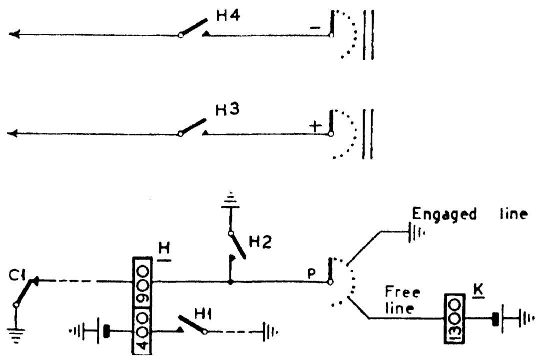
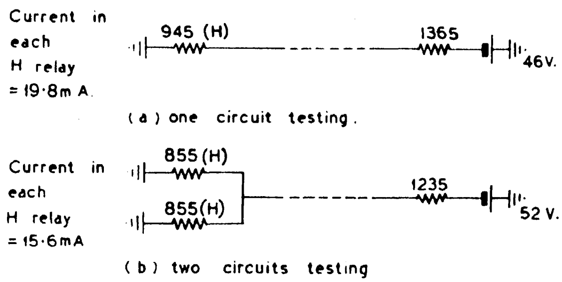


FIG. 262. BATTERY TESTING CIRCUIT WITH LOCAL HOLD CONDITIONS

that there is insufficient current for two relays to operate even under the most adverse conditions o battery voltage and relay resistance. Fig. 263 shows the circuit conditions of Fig. 262 in schematic form. The upper portion of the illustration shows the normal conditions when one H relay tests a free outlet. Exchange equipment is designed to operate with an exchange battery voltage of from 46 V to 52 V and a tolerance of + or − 5 per cent



$$\text{Ratio} = \frac{\text{operate current}}{\text{non-op. current}} = \frac{19{\cdot}8}{15{\cdot}6} = 1{\cdot}27$$

FIG. 263. CURRENTS IN SWITCHING RELAY WITH CIRCUIT OF FIG. 262

is allowed on the nominal value of relays and resistors. The minimum current under the most adverse conditions when one H relay tests is therefore some 19·8 mA. The comparable conditions when two H relays attempt to switch to the same outlet are shown in the lower portion of the illustration. In this case there is the greatest danger of dual switching when the exchange voltage is 52 and when all the resistance values are at the lower limit. Taking into consideration these factors, the maximum current in each H relay is some 15·6 mA. It will be seen, therefore, that to make the circuit immune from dual switching, it is necessary to design an H relay which will operate on 19·8 mA but will not operate on 15·6 mA, i.e. a relay which has an operate/non-operate current ratio of 1·27. Such close margins are very difficult to achieve in practice unless abnormal maintenance costs are incurred. Circuits utilizing the element shown in Fig. 262 do not in fact prevent double connexions should two circuits test the same outlet concurrently.

It is clear from Fig. 263 that the current in each H relay when two such relays test the same outlet can be reduced by making the resistance of the operate coil of H small in relation to the total resistance of the circuit. It can readily be shown by an application of Ohm's law that, if the voltage limits are fixed between 46 and 52 and the resistance of the relay coils is within + or − 5 per cent of the nominal value, then:

Minimum operate current with one testing relay

$$= I_1 = \frac{46}{1{\cdot}05(X + Y)} \qquad (1)$$

where X = resistance of testing relay coil, and
Y = resistance of outlet circuit.

Similarly, the maximum current in each relay during dual testing conditions

$$= I_2 = \frac{1}{2} \times \frac{52}{0{\cdot}95(X/2 + Y)} \quad . \quad (2)$$

From which

$$\frac{I_1}{I_2} = 0{\cdot}8 \times \frac{X + 2Y}{X + Y} \quad . \quad . \quad (3)$$

Or, if $Y/X = Q$,

then $$\frac{I_1}{I_2} = 0{\cdot}8 \times \frac{1 + 2Q}{1 + Q} \quad . \quad . \quad . \quad (4)$$

The ratio of I_1/I_2 has been calculated for values of Q from 1 to 10 and the results are shown in Fig. 264.

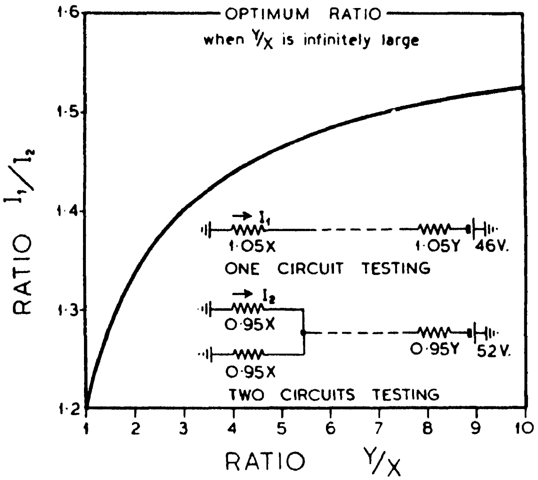


FIG. 264. SHOWING HOW MARGIN AGAINST DUAL SWITCHING IS AFFECTED BY RESISTANCE VALUES

It will be noted that as the value of Q (i.e. the ratio Y/X) is increased, the margin between the minimum operate current and the maximum non-operate current (i.e. the ratio of I_1/I_2) increases rapidly at first, but later levels out. The maximum ratio of I_1/I_2 is (under the above conditions) 1·6 and occurs when Y/X is infinitely large. It is clear that an appreciable improvement in the I_1/I_2 ratio can be obtained by making the resistance of the tested circuit (Y), say, up to six or even seven times the resistance of the H relay, but there is very little to be gained by increasing the ratio (Y/X) very much beyond this limit.

It should be noted that the static Ohm's law value of current in the circuit has so far been assumed. This is not a strictly correct analysis of the conditions since the H relay operates whilst the current is still rising in the testing circuit. The potential at the bank contact (which is the determining factor when two H relays test together) is governed partly by the ohmic resistance values and partly by the back e.m.f. due to the self-inductance of the relays. If the K relay is not required and the testing circuit consists of a non-inductive resistance, then there is a higher probability of dual switching than when the K relay is included.

There is a further very important aspect to be considered. In cases where the switching relay is required to interrupt an automatic drive circuit, then the operate time of the H relay must be kept to a minimum. For a given physical construction, the operate time of any relay is determined by the ratio of its inductance to the total resistance of the circuit (i.e. the L/R ratio). The inductance of a relay is directly proportional to the square of the number of turns and, with a relay of given design, the resistance of the winding is also roughly proportional to the square of the turns. Hence the minimum operate time is obtained if the resistance of the testing relay (X) is kept low, as compared with the resistance of the remainder of the circuit (Y). This is a further argument for designing a circuit in which the ratio Y/X is as large as possible.

The requirements of fast operation and immunity from double switching both call for a circuit in which the testing relay is of low resistance in conjunction with a resistance of high value in the testing battery supply circuit. A large Y/X ratio can be obtained either by decreasing the resistance of the testing relay (X) or by increasing the resistance (Y) in series with the battery. In the former case the number of turns on the testing relay is reduced, whilst the latter merely reduces the value of the current in the circuit. Either or both of these measures unfortunately reduces the number of ampere-turns available in the operate coil of the testing relay. This factor places a definite limit upon the value of Y/X and, where a testing relay is very heavily loaded, the large number of ampere-turns necessary to operate it sometimes prevents the adoption of circuit constants which will give an adequate margin (i.e. I_1/I_2 ratio) to avoid double connexions.

It is interesting to see how the number of ampere-turns available is determined by the ratio Y/X. In Fig. 265 the ampere-turns have been calculated for a fully wound relay of the 3000 type. It will be noted that with a relay resistance of, say, 1000 Ω, the ampere-turns available fall from about 400 to about 70 when the ratio Y/X is increased from 1 to 10. The difference is very much greater when the operate coil of the testing relay is of lower resistance. The ampere-turns available in the testing relay depend not only on the ratio of Y/X

but also upon the actual value of X. In Fig. 265, 4 curves have been drawn for relay resistance values of 1, 10, 100 and 1000 Ω. If it is assumed that the load on the switching relay is such as to require 400 ampere-turns for its operation, then, if the relay resistance is 1000 Ω, the requirements can be met only by adopting a circuit with a Y/X ratio of 1 or less. If, however, the relay resistance is reduced to, say, 100 Ω it is possible to obtain 400 ampere-turns in the relay with a circuit having a Y/X ratio of 5—with a consequent greater margin to prevent dual switching and a much improved operating speed. There is, of course, a lower limit to the value of the testing relay resistance on account of the heavy currents involved. The question of "fire risk" must also be very carefully considered.

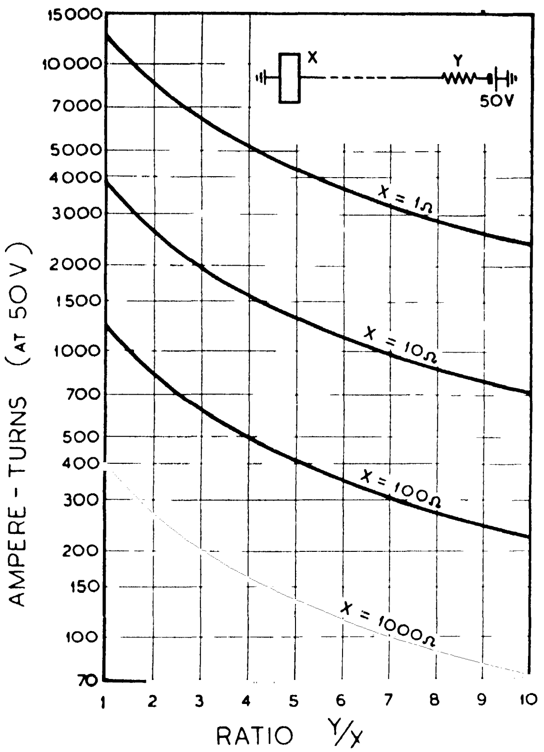


Fig. 265. Relationship Between Ampere-turns in Switching Relay and Resistance Values

To summarize:

(a) Dual switching can be prevented in a battery testing circuit only when the resistance of the operate coil of the testing relay is low compared with the resistance of the P-wire circuit of the tested outlet. Practical considerations require a minimum ratio of, say, 5 to 1, but there is little to be gained by increasing the ratio beyond, say, 10 to 1.

(b) The operating lag of the testing relay is determined by the L/R value of the circuit. This value is largely independent of the resistance of the testing relay coil but can be decreased by raising the ratio mentioned under (a).

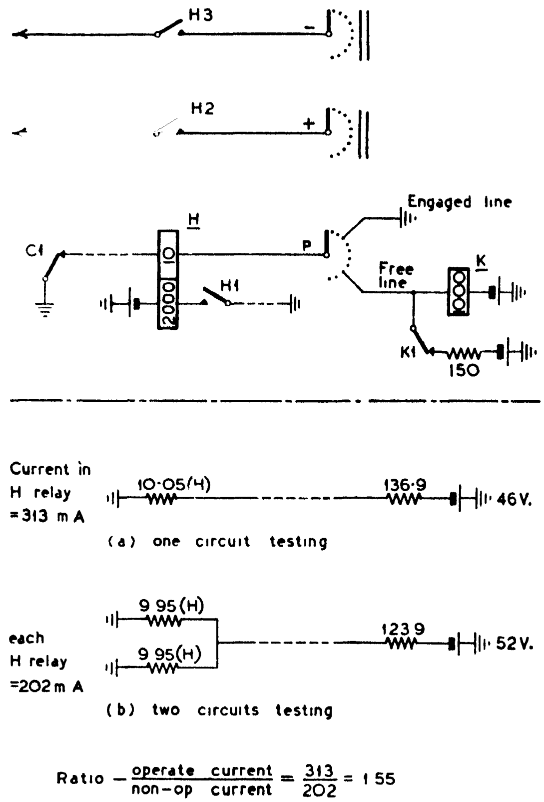


Fig. 266. Battery Testing Circuit with Low Resistance Operate Coil

(c) The ampere-turns available to operate the testing relay decrease rapidly as the ratio of outlet resistance to relay resistance (Y/X) is increased. The adoption of a low resistance operate coil on the H relay enables a high Y/X ratio to be utilized, whilst providing the required number of ampere-turns.

(d) The components of the testing circuit should, as far as possible, be "self-protecting," and there must be no risk of fire under fault conditions.

Battery Testing Circuit with Low Resistance Operating Coil. Fig. 266 shows a variation of the previously considered battery testing circuit with resistance values which enable the circuit to be made reasonably immune from double connexions.

The operate coil of the H relay has been reduced to 10 Ω, whilst a 150 Ω resistor is placed in series with the battery on a free outlet. The time constant of this circuit is comparatively low due to the small number of turns on the 10 Ω coil of H, and hence the circuit is suitable for use in conjunction with an automatic drive circuit where rapid operation of the testing relay is required. The low resistance values result in a very heavy current (approximately $\frac{1}{3}$ of an ampere) in the P-wire circuit. This current cannot be allowed to persist, and arrangements are therefore made to increase the resistance of the circuit once the H relay has operated by the inclusion of a K contact which disconnects the

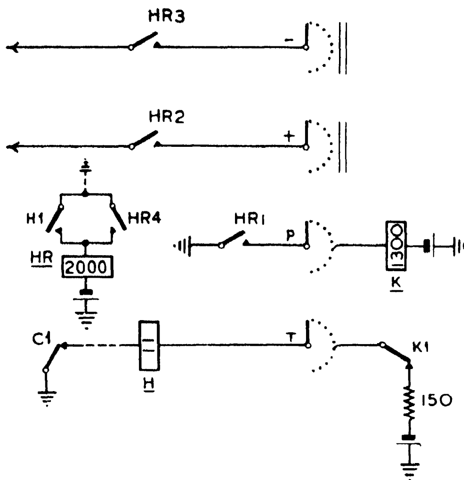


Fig. 267. Battery Testing Circuit with Single-coil Low Resistance Relay

initial testing battery on the operation of relay K in the circuit seized. It will be noted that the low resistance of the operate coil of H makes it unnecessary to apply a separate guarding earth (contact $H2$, Fig. 262) to the P-wire after operation of the switching relay.

The lower portion of Fig. 266 shows the limits within which the H relay must be adjusted to make the circuit immune from double connexions. The minimum operate current when one H relay tests is now 313 mA whilst, if two relays test the same outlet, the current in each is only 202 mA. This gives a ratio of operate current/non-operate current of 1·55 as compared with the figure of 1·27 with the circuit of Fig. 263. It was shown in Fig. 264 that the maximum ratio theoretically obtainable is 1·6, and hence the circuit with a 10 Ω H relay coil approaches the best possible working conditions with this particular circuit arrangement.

Battery Testing Circuit with Low Resistance Single-coil *H* Relay. One further improvement of the simple battery testing circuit so far considered is possible. In Fig. 267 a single-coil testing relay H is employed in conjunction with a relief relay HR. This arrangement obviates the necessity for a hold coil on the testing relay and thereby makes available the whole of the relay winding space for the operate winding. Furthermore, the adoption of the relief relay HR makes it possible to design a testing relay (H) with a very light load. The net result is a circuit which gives the maximum possible margins to prevent double connexions, together with a very low operate lag of the switching relay. The 11 Ω value of relay H has no particular significance. It so happens that a fully wound bobbin of a 3000 type relay will accommodate 1760 turns of No. 27 S.W.G. enamelled wire with a resistance of 11·2 Ω approximately. This switching element will be found in a number of circuits such as a linefinder where it is particularly important to guard against double connexions and where rapid operation of the testing relay is essential. In Fig. 267 the K relay is operated over an entirely separate arc of the selector bank from an earth supplied by a contact of relay HR. Although this involves an additional wiper and bank, it has the advantage of excluding the K relay from the initial testing circuit (when this is permissible).

Battery Testing Circuit with Marginal Hold Conditions. The battery testing circuits so far described have relied upon marginal *operate* conditions to render the circuit immune from double switching should one outlet be tested concurrently by two searching selectors. As an alternative to this arrangement, it is possible to design a battery testing circuit where no attempt is made to prevent two testing relays operating to the same battery condition on the P-wire but where the characteristics of the holding circuit are adjusted to prevent two relays *holding* to the same outlet. It follows that any circuit designed to prevent double connexions by the use of marginal hold conditions, must be arranged so that the relay is held over the P-wire and not by means of a local circuit as in the case of the previous battery testing circuits.

Fig. 268 shows a typical arrangement. When testing conditions are established, both coils of the H relay are applied in series to the P-wire. If battery potential is encountered, relay H operates and at **$H1$** provides a holding circuit for relay H by the current through the 25 Ω winding to the battery in the seized circuit. It will be noted that the use of a low resistance holding coil obviates the necessity for providing a separate H contact to apply earth to the P-wire for engaging purposes. If two selectors test the same outlet concurrently, both H relays will operate to the battery potential on

the P-wire, but the hold current of each relay is so adjusted that it is not possible for two relays to hold on their 25 Ω coils to the common 250 Ω battery in the seized circuit. Both H relays now release and hunting continues until the next free outlet is found. Variations of hunting speed and relay adjustment make it extremely improbable that two selectors testing one outlet concurrently would continue to test successive outlets at the same time.

It is clear that the resistance values in the holding circuit must be determined by the considerations already discussed for circuits having marginal operate characteristics. The ratio of the resistance in series with the battery to the resistance of the *hold* coil of H must be made as great as possible, consistent with an adequate number of ampere-turns on the relay winding. This gives the greatest margin between the specified hold and release currents of the relay. The marginal hold battery testing circuit is, generally speaking, somewhat better than the circuit designed to give marginal *operating* conditions due to:

(*a*) The ampere-turns required to hold a relay are appreciably less than the ampere-turns necessary to operate the relay. Hence under given conditions the ratio of the resistance in series with the battery to the resistance of the hold coil can be made somewhat greater.

(*b*) The full winding space is effective during the operation of the relay when the maximum tractive force is required.

(*c*) The L/R ratio of the operate circuit can be made low, thereby decreasing the operating time of the testing relay.

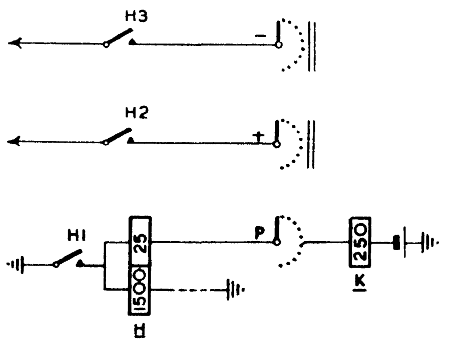


FIG. 268. BATTERY TESTING CIRCUIT ARRANGED FOR MARGINAL HOLD CONDITIONS

Apart from these factors, the use of marginal operate or marginal hold testing circuits is to some extent governed by the circuit requirements. Marginal operate circuits are of value when local holding is required, but marginal hold circuits are the only solution where the switching relay is to be held from the condition on the P-wire.

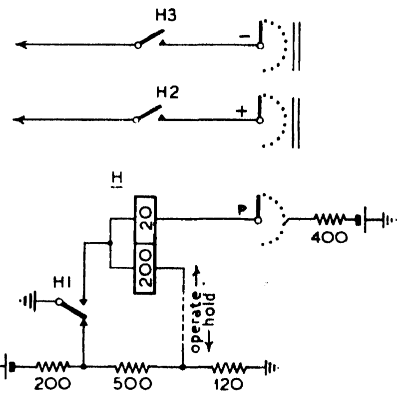


FIG. 269. BATTERY TESTING CIRCUIT WITH DIFFERENTIAL HOLDING CONDITIONS

Battery Testing Circuit with Differential Holding Conditions. Although in certain circumstances a battery testing circuit with marginal hold facilities may offer certain advantages, it should be realized that freedom from dual switching can be obtained only by specifying hold and release current values which are within comparatively close limits. It has been shown that, if the nominal resistance values may vary by ± 5 per cent and the exchange battery voltage may range from 46 to 52 V, it is not theoretically possible to obtain a hold/release current ratio greater than 1·6. In practice the ratio obtainable is somewhat less owing to the practical requirement of obtaining adequate ampere-turns in the hold coil.

Fig. 269 shows a recent and much improved circuit based on the principle of marginal hold conditions. When a free outlet is found relay H operates on both coils in series from the earth at $H1$ via the 500 Ω resistor to the 400 Ω battery on the P-wire. After switching, the operation of contact **$H1$** maintains a holding current for the H relay through the 20 Ω winding to the battery on the P-wire, but also reverses the current in the 200 Ω winding to the local battery via the 500 Ω and 200 Ω resistors (the 120 Ω resistor acting as a shunt on the relay winding). The number of turns on the two windings of relay H and the current values are adjusted so that the magnetic effect of the 20 Ω winding predominates, thereby maintaining the relay in its operated condition. If the holding ampere-turns in the 20 Ω winding on a normal (single) connexion are, say, 200 A.T., then the opposing ampere-turns in the 200 Ω winding are adjusted to 200/2 = 100 A.T. If two circuits

test the same outlet together, the ampere-turns in each 20 Ω coil are very approximately 200/2 = 100, but the ampere-turns of the opposing windings

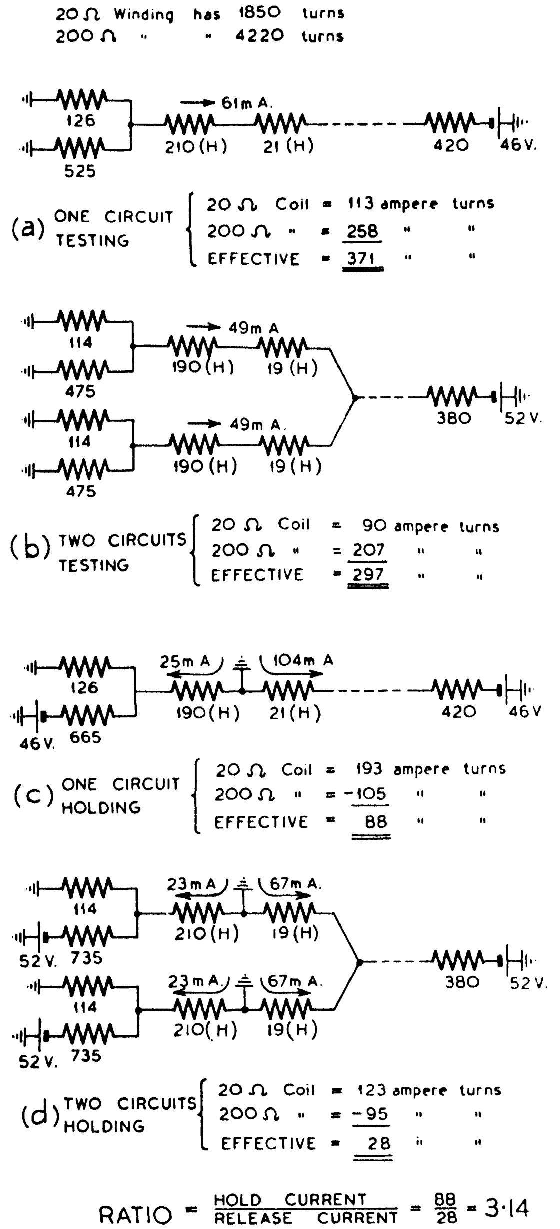


Fig. 270. Current in Testing Relay of Fig. 269 Under Various Conditions

remain the same. The effective ampere-turns are therefore zero under these conditions and the relay releases. It is clear that theoretically the ratio of effective hold current on single connexions to that on dual connexions is 2 : 0, which gives a very much greater margin than the ratio of some 1·5 or 1·6 : 1 previously obtained. These theoretical margins are, of course, somewhat reduced by variations of resistance value and battery voltage, although the effects of the latter are much reduced since variations of battery voltage equally affect both coils of the relay under certain conditions and need not be considered.

It is interesting to examine in some detail the operate and hold conditions of the circuit illustrated in Fig. 269. A typical relay having 1850 turns on its 20 Ω winding and 4220 turns on its 200 Ω winding has been considered in Fig. 270. At (*a*) the operating current under the most adverse conditions of battery voltage and resistance values has been calculated. A current of about 61 mA flows through both windings in series which provides some 113 A.T. in the 20 Ω coil and approximately 258 A.T. in the 200 Ω coil. The effects of both coils are additive at this stage, so that the effective ampere-turns are 371. At (*b*) the effect of two *H* relays testing together is considered. In this case the greatest danger of dual switching occurs when the battery voltage is a maximum and the relay resistances are at their lower limits. Some 297 A.T. are available in each relay under these conditions, and it is clear that the circuit will not allow an adequate margin to discriminate against dual switching by virtue of the margin between the operate current in the two cases. The circuit values are, in fact, so arranged that no attempt is made to provide marginal operate conditions.

At (*c*) and (*d*) the number of ampere-turns has been calculated when one relay holds and when two relays attempt to hold to the same battery. When one *H* relay only holds to the 400 Ω battery, there are some 193 A.T. in the 20 Ω coil and approximately 105 opposing A.T. in the 200 Ω coil. This gives a net value of 88 A.T. which is adequate to hold the relay. When two relays attempt to hold to the same battery, the smaller current in the 20 Ω coil reduces the ampere-turns available from 193 to 123, but at the same time the opposing ampere-turns are (even allowing for extremes of resistance and battery voltage) reduced only from 105 to 95. The maximum effective ampere-turns, therefore, under dual holding conditions are only some 29. Thus, the circuit requirements necessitate a relay which will hold with 88 A.T. but which will release with 29 A.T., i.e. the arrangement gives a hold/release ratio of some 3 : 1 as compared with the theoretical maximum of 1·6 : 1 of the earlier circuits.

Once switching has been completed and the *P*-wire is guarded against intrusion, there is no

further danger of dual switching, and hence it is possible at this stage to disconnect the circuit of the 200 Ω coil to prevent unnecessary waste of energy.

Automatic Hunting with Battery Testing. Fig. 271 shows a battery testing circuit of the differential-hold type used in conjunction with a simple drive element. The drive circuit is of the self-interrupted type and is entirely separate from the testing circuit. The satisfactory operation of this circuit depends upon providing a testing relay which is sufficiently fast in operation to cut the drive when a free outlet is encountered. To assist in this matter, the inductive relay (A) on the P-wire is shunted by a 400 Ω non-inductive resistor. By this means the current build-up in the H relay can be made much more rapid.

Automatic search is started by the operation of contact **$L2$**, whilst **$L1$** prepares the switching relay. When a free outlet is encountered, relay H operates over both coils in series to the 400 Ω battery on the P-wire. **$H1$** disconnects the drive circuit, whilst **$H2$** completes the holding circuit for H. The A relay in the outlet seized now operates, and the **$A1$** contact disconnects the 400 Ω resistor to reduce the battery drain after the completion of switching.

If the battery testing circuit is not of the quick operating type (or if the switching relay is heavily loaded), then the circuit arrangements of Fig. 271 cannot be employed. Under such conditions it is

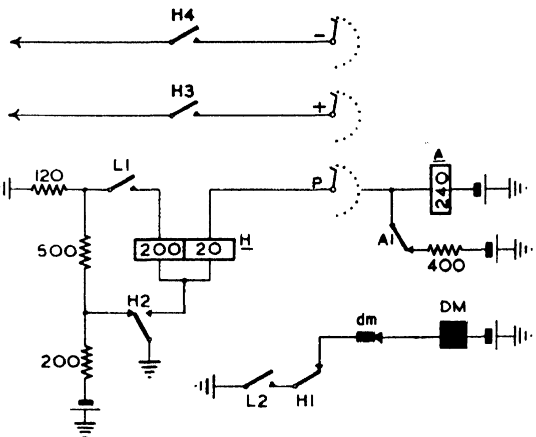


Fig. 271. Battery Testing Circuit with Independent Self-interrupted Drive

necessary to provide a drive circuit of the interacting relay type in which the drive is more closely co-ordinated with the testing circuit. Fig. 272 gives a typical arrangement. As before, contact **$L1$** is closed to start the drive circuit, and the earth extended through the 1500 Ω coil of H operates relay G (the current in this circuit is insufficient to operate the H relay). **$G1$** now completes the selector magnet circuit and, when the armature of

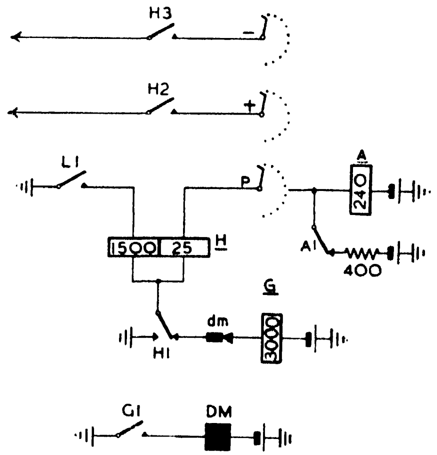


Fig. 272. Battery Testing Circuit with Interacting Relay Type of Rotary Drive

the magnet is attracted, the ***dm*** springs open to release relay G. $G1$ in turn de-energizes the magnet. The wipers are thus stepped to the next contact, and the process continues until such time as a battery is encountered on the P-wire. This battery potential, applied through the 25 Ω coil of H, shunts the G relay and prevents its further operation. H now operates with both coils in series, and **$H1$** disconnects the G relay circuit whilst at the same time it provides a holding circuit for H and a low resistance guarding earth on the P-wire.

It is desirable to retain the 400 Ω non-inductive resistor on the P-wire of a free outlet to prevent the operation of relay G when the wipers step to a disengaged contact. (If the tested circuit consisted merely of the highly inductive A relay, the change of potential at the junction of the two coils of relay H would be comparatively slow, and there is a danger of the G relay operating during this period.)

Slow Speed Drive. With the circuit arrangements of Figs. 271 and 272, the switching relay operates before the A relay in the outlet which has been seized. In some circumstances (e.g. when a final selector tests into a subscriber's line circuit), it is important that a relay in the tested circuit should be operated before the testing circuit switches to it. Earth testing circuits cannot be used in such circumstances, due to the fundamental fact that there can be no circuit change in the seized outlet until such time as the switching relay has completed its function. Probably the most satisfactory arrangement is the use of a battery testing circuit with a

heavily loaded relay and a high resistance operate coil. We have seen that such a circuit is normally slow in operation—especially when it is energized in series with a further relay in the *P*-wire circuit of the outlet under test. (The very high inductance of the two relays in series, and the comparatively high L/R ratio of the testing circuit, produce a very slow rise of current.) Even with this arrangement care must be taken in the design to ensure that there is an adequate margin between the operate time of the relay in the circuit tested and the operate time of the testing relay.

In some cases, notably in final selectors where the circuit is required to search over all the lines of a small P.B.X. group, the battery testing circuit described above must be used in conjunction with an automatic drive feature. In these circumstances it is necessary either to utilize a very low hunting speed (to ensure that there is adequate time for switching when a free outlet is encountered) or to design the circuit so that the free condition auto-

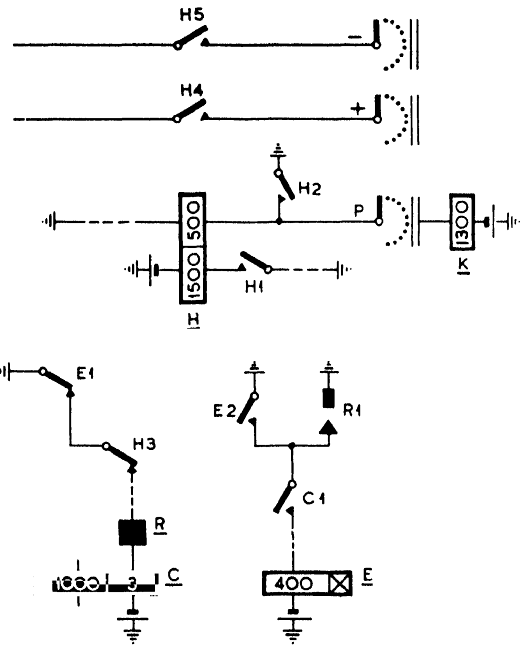


FIG. 273. BATTERY TESTING CIRCUIT WITH SLOW SPEED DRIVE (PRE-2000 TYPE)

matically arrests the drive circuit—irrespective of the operate time of the switching relay.

Battery Testing Circuit with Slow Speed Drive (Pre-2000 Type). Fig. 273 shows a typical slow speed drive circuit as used on pre-2000 type final selectors. The slow drive speed is obtained by utilizing the operate and release lags of two relays (*C* and *E*). When automatic drive is required, the circuit is completed via *E*1 and *H*3 to energize the selector rotary magnet and the *C* relay in series.

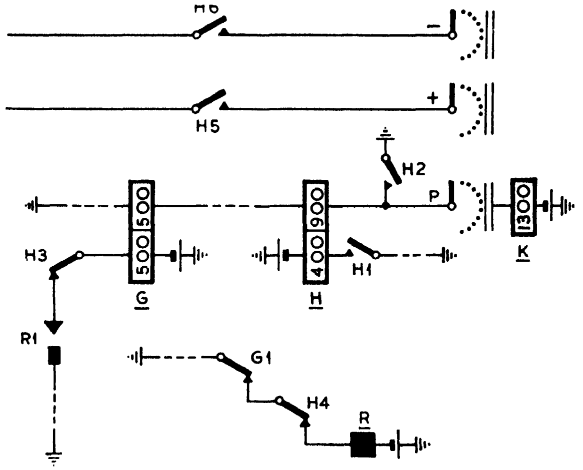


FIG. 274. BATTERY TESTING CIRCUIT WITH SLOW SPEED DRIVE (2000 TYPE)

When the rotary magnet armature is operated, the ***R*1** contacts close and complete the circuit for relay *E*. This relay is provided with an armature-end slug so that there is a slight operate lag before ***E*2** closes to provide a holding circuit for *E* independent of the ***R*1** contacts (but under the control of ***C*1**). ***E*1** disconnects the circuit of the magnet and the *C* relay, and after a further period of lag the *C*1 contacts open to disconnect the hold circuit of relay *E*. There is now a further delay during the release lag of the *E* relay before the rotary magnet circuit is re-established at *E*1.

By the above arrangement, the *E* relay is energized for a period equal to the operate lag of *E* plus the release lag of *C*. Similarly, the *E* relay is released (to energize the rotary magnet and *C* relay) for a period equal to the operate time of the rotary magnet plus the operate time of the *E* relay. Due to the comparatively long period of energization, the *E* relay has a release lag of reasonable length, and the resultant speed of interaction is correspondingly low. It should be mentioned that, when this circuit is employed on final selectors, the *C* and *E* relays are also used in the impulsing circuit of the selector.

Battery Testing Circuit with Slow Speed Drive (2000 Type). The circuit of Fig. 273 is designed on the assumption that the speed of search should be such that the wipers rest on each bank contact for a sufficiently long time for the testing circuit to operate. It has already been seen that this principle necessarily involves a very low speed of

search. In some cases, especially where search over a large number of lines is required, this very low speed of hunting may be a disadvantage. In 2000 type circuits a somewhat different principle is employed. Fig. 274 shows the arrangement in simplified form.

When automatic hunting is required, a circuit is completed for the rotary magnet via *G*1 and *H*4. The rotary magnet operates and the ***R*1** contacts close as the wipers are moved to the next contacts. Relay *G* is now energized and at ***G*1** breaks the circuit of the rotary magnet. This process continues until a free outlet (or a marked contact) is encountered. The process is so far identical with that of the simple interacting type of drive circuit illustrated in Fig. 252. When a battery potential is encountered on the *P*-wire, the current commences to rise in the second coil of the *G* relay, the operate coil of the *H* relay and in the winding of the relay (*K*) in the outlet seized. When this testing circuit is first completed, the *G* relay is already energized via ***R*1** and *H*3. A comparatively low value of current in its second winding will, under these conditions, hold the *G* relay. The values are so adjusted that, when the wipers move on to a contact with battery potential, the current in the *P*-wire, by the time the *R*1 contacts break, is sufficient to hold the *G* relay on its second coil. The current at this time may be, and usually is, insufficient to operate the *H* relay and the *K* relay, but rotary drive is arrested by the holding of the *G* relay so that an unlimited time is available for the completion of switching. As the value of current still further rises in the *P*-wire circuit, the *K* relay operates and is followed by the operation of relay *H*. Contact ***H*3** disconnects one coil of the *G* relay, whilst ***H*4** disconnects the rotary magnet circuit in readiness for the release of *G*1. ***H*1** provides a local holding circuit for *H*, whilst ***H*2** applies guarding earth to the *P*-wire and allows relay *G* to release. The remaining contacts of the *H* relay complete the switching operation in the usual manner.

Automatic Hunting over P.B.X. Groups (Pre-2000 Type). Certain final selector circuits are designed to accommodate ordinary single subscribers' lines and also small P.B.X. groups of from 2 to 10 lines. The circuit must be designed so that, if an ordinary line is dialled, the selector will test that line and if the line is engaged will return engaged tone to the caller. If, however, the first line of a P.B.X. group is dialled, the circuit is required to provide automatic search over all the lines of the P.B.X. group and to return busy tone only if all lines in the group are engaged. In addition, night service facilities are required on P.B.X. lines so that, if any number of the P.B.X. group other than the first is dialled, the selector will behave as for an ordinary line, i.e. it will test that line only and will return busy tone if the line is engaged.

Fig. 275 shows the switching and hunting elements of a pre-2000 type final selector circuit with P.B.X. facilities. The switching circuit is of the battery testing type, whilst the automatic drive circuit over the lines in a P.B.X. group is based on the principle already considered in Fig. 273. An additional relay *HS* is provided to effect discrimination when a P.B.X. group is dialled. When the circuit is seized, the *C* relay is pre-operated for impulsing purposes from the earth at ***B*1** via *NR*1 and *N*1. This pre-operate circuit is broken at ***N*1** as the wipers are stepped vertically, but the *C* relay is maintained for the vertical impulse train by pulses of current in its 3 Ω winding. At the end of the vertical impulse train, *C* releases and at *C*2 provides a circuit for the *E* relay which at ***E*1** re-establishes the pre-operate circuit of *C*. After the operation of ***C*2**, the *E* relay is held via ***C*2** and ***E*2** to the earth at ***B*2**. The subscriber now dials the rotary impulse train, and at the first rotary step the pre-operate circuit of *C* is disconnected at ***NR*1**. The *C* relay, however, holds during the impulse train due to the current in its 3 Ω winding but releases after a delay period on completion of the impulse train.

In addition to the normal, negative, positive and *P* banks, a special solid metal arc known as the P.B.X. or auxiliary arc is provided. This arc is illustrated in Fig. 104, and is arranged so that contact screws can be inserted in positions corresponding to the bank contacts of the selector. A double wiper with leading and trailing blades is used in conjunction with the P.B.X. arc. The circuit is so arranged that, on ordinary lines where no hunting is required, the screws are omitted from the P.B.X. arc. Spare lines are similarly treated but screws are inserted in the holes of all except the last line of each P.B.X. group. In Fig. 275 the connexions are shown for a level where the first 4 contacts are associated with one P.B.X. and the 7th, 8th, and 9th contacts relate to a second P.B.X. on the same level. The 6th contact is assumed to be an ordinary line, whilst the 5th and 10th contacts are shown as spare. The wipers are positioned so that the leading wiper occupies the same relative position as the line and *P* wipers.

If the number dialled corresponds to that of an ordinary line, no screw is provided in the P.B.X. arc, and hence there is no electrical potential on the leading wiper. On the release of *C*3 at the termination of the rotary impulse train, there is

no circuit for the operation of the *HS* relay and contact *C*1 completes the testing circuit for the *H* relay to the earth at ***B*2** via ***E*2**. If the line is free, *H* operates to the battery on the *P* bank and switches the call. The release of *C*2 also disconnects

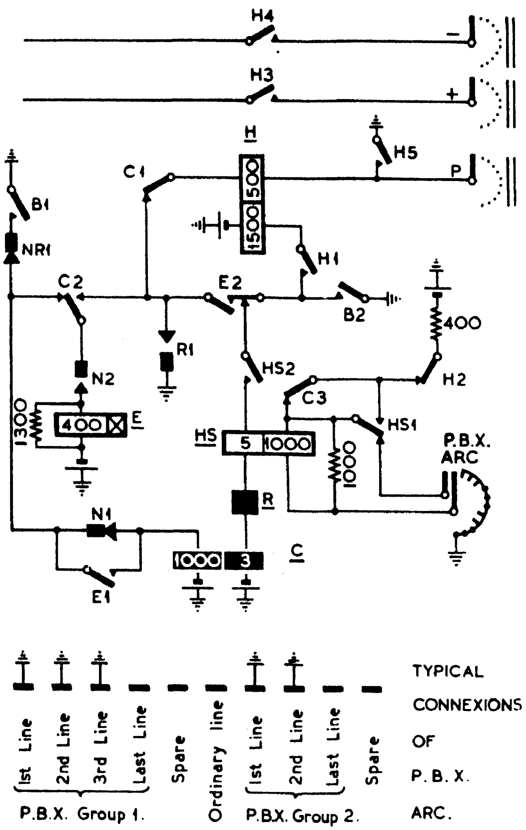


FIG. 275. METHOD OF PROVIDING AUTOMATIC SEARCH OVER LINES OF A P.B.X. GROUP (PRE-2000 TYPE)

the circuit of the *E* relay which, after a delay period, breaks the testing circuit at *E*2. If the *H* relay is not operated by this time, separate elements (not shown in Fig. 275) return the engaged signal to the caller.

If, on the other hand, the first line of a P.B.X. group is dialled, the leading wiper is in contact with the earth connected screw of the P.B.X. arc at the time when contact *C*3 releases. A circuit is now provided for the operation of relay *HS* on its 1000 Ω coil from the 400 Ω battery via *H*2 and *C*3. ***HS*1** provides a holding circuit for *HS* independent of *C*, whilst ***HS*2** prepares the rotary hunting circuit. *C*2 disconnects the circuit of relay *E* as before and, after the release lag period, *E*2 completes the circuit for the rotary magnet from earth at ***B*2**, *E*2, ***HS*2** and the 5 Ω coil of *HS* to the battery at the *C* relay. The *C* relay re-operates over this circuit, and at approximately the same time the ***R*1** contacts close. A re-operate circuit is now provided for the *E* relay from the earth at ***R*1** via ***C*2** and ***N*2** and, after a short lag, ***E*2** re-operates to disconnect the rotary magnet circuit. The restoration of the rotary armature allows contacts *R*1 to open, but the *E* relay is held via ***C*2** and ***E*2** until such time as the *C* relay releases. When this circuit is broken by the release of *C*2, there is a further delay due to the release lag of *E* before the rotary magnet circuit is re-established at *E*2. As before, the testing circuit is completed during the release lag of relay *E* so that, if the line is free, the *H* relay will operate and switch the call.

If the line is engaged, the interaction of the rotary magnet, the *C* relay and the *E* relay continues for so long as the ***HS*2** contact is closed or until a free line is encountered. When the leading wiper of the P.B.X. arc reaches the last contact of the P.B.X. group, the absence of a screw in the P.B.X. arc disconnects the 1000 Ω coil of the *HS* relay which releases on the operation of ***E*2** to break the hunting circuit at *HS*2. It will be noted that the P.B.X. wipers are not of the bridging type. Arrangements are therefore necessary to hold the *HS* relay independent of the conditions on the P.B.X. arc whilst the wipers are passing from one screw to the next. During this period, the current in the 5 Ω coil of *HS* maintains the relay, whilst the initial operating circuit is disconnected at the leading wiper. The 1000 Ω shunt across the high resistance coil of relay *HS* is provided to prevent arcing at the P.B.X. wipers which would otherwise occur due to the high induced e.m.f.s resulting from the current surges in the 5 Ω coil.

If an intermediate line in a P.B.X. group is dialled, no hunting is required and the circuit should behave as when an ordinary line is dialled. In these circumstances, the leading and trailing P.B.X. wipers both encounter earth conditions on adjacent screws in the P.B.X. arc. On the release of *C*3, the earth encountered by the trailing wiper effectively shunts away the battery from the *HS* relay and thereby prevents its operation.

Automatic Hunting over P.B.X. Groups (2000 Type). Two-motion selectors were not originally designed to accommodate a P.B.X. arc and its presence introduces some congestion—with the resultant maintenance difficulties. For the same reasons it is not practicable to provide a P.B.X. arc which will give hunting facilities on both 100's groups of 200-line final selectors. 200-line final selectors of the pre-2000 type are therefore limited to P.B.X. facilities on one 100-line group only. It

is of very great advantage to have P.B.X. facilities on all lines of a 200-line final selector, and on the introduction of the 2000 type mechanism, a new P.B.X. hunting circuit based on the provision of ordinary banks for discrimination purposes was designed.

The circuit elements of a typical 2000 type circuit are shown in Fig. 276. The rotary drive circuit is the type already considered in Fig. 274. The use of ordinary banks with insulated contacts for discriminating purposes instead of the earthed arc of the pre-2000 type selectors enables a simpler discrimination scheme to be adopted. The *P*2 bank is the discriminating level and the first line of every P.B.X. group is marked on this bank by a battery potential. No marking condition is provided on the intermediate lines, but the last line of the group is distinguished by earth potential on the *P*2 bank. Ordinary lines and spare lines have no marking condition.

When the selector is seized, the *C* relay is pre-operated by contact **B1** and, at the first vertical step, the closure of the off-normal contacts ***N*1** applies earth from ***B*3** via *NR*2 and *E*4 to short-circuit the pre-operate winding of *C*. The *C* relay holds, however, during the vertical impulse train due to the pulses of current in its 5 Ω winding, but during the interdigit pause *C* releases and at *C*2 completes a circuit for the *E* relay. ***E*4** in operating removes the earth from the 700 Ω coil of the *C* relay and allows it to re-operate. The earth is, however, re-applied by the operation of contacts ***NR*2** at the first rotary step, and the *C* relay is now held for the duration of the rotary impulse train under the control of the current pulses in its 5 Ω winding. During this period, the *E* relay is held via **C2** and **E1**. At the end of the rotary impulse train, *C* releases and at *C*2 disconnects the circuit of relay *E*. The *E* relay is slow to release, but at the end of its release period the restoration of *E*4 allows relay *C* to re-operate by the removal of the short-circuiting earth from the 700 Ω winding. At the same time the release of *E*2 allows the *G* relay to operate via *H*4, *E*2, *HS*4, ***NR*2**, ***N*1**, and ***B*3**.

During the release lag of *E* plus the operate lag of *C*, the 250 Ω coil of relay *HS* is applied to the *P*2 wiper via ***B*4**. If the contact on which the wipers are standing corresponds to an ordinary line, a spare line, or an intermediate line of a P.B.X. group, the absence of battery on the *P*2 arc prevents the operation of relay *HS*. Under these conditions the 900 Ω coil of relay *H* is applied to the *P*1 wiper during the period for which *C*1 is released. If the line is disengaged, the *H* relay operates but, if, due to the line being engaged, *H* does not operate before *E* releases, the *G* relay operates and the engaged signal is returned to the calling party. (The circuit arrangements for the return of the engaged signal are considered later.)

If the contact to which the wipers are stepped by the calling party is the first line of a P.B.X.

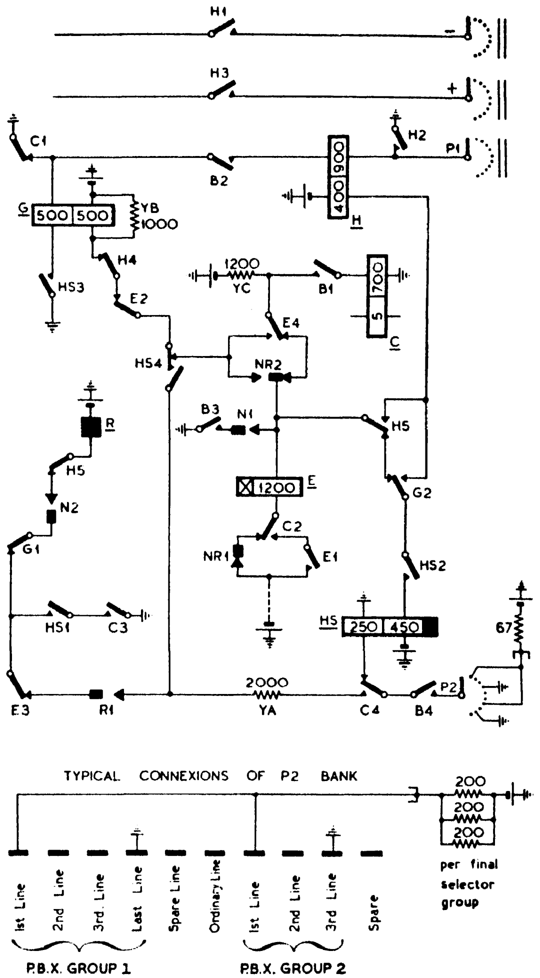


FIG. 276. AUTOMATIC SEARCH OVER LINES OF A P.B.X. GROUP (2000 TYPE)

group, battery is extended from the *P*2 arc during the released period of the *C*4 contact to operate the *HS* relay on its 250 Ω coil. ***HS*2** establishes a holding circuit for *HS* under the control of relays *G* and *H*. Relay *C* now operates as described above, and, at **C3**, earth is applied via ***HS*1**, *G*1, ***N*2**, and *H*5 to energize the rotary magnet. As the magnet armature is attracted, contacts ***R*1** close and extend earth from **C3** via ***HS*4**, *E*2, and *H*4 to operate the **G** relay. **G1** now disconnects the rotary magnet circuit and in due course the *R*1 contacts restore

The circuit for *G* is now broken and the restoration of *G*1 re-establishes the rotary magnet circuit. This process of interaction between the *G* relay and the rotary magnet continues until a free line is encountered or until rotary hunting is stopped at the last line of the P.B.X. group.

If a free line is encountered, the earth applied at ***HS*3** holds relay *G* to arrest the rotary drive circuit and allows relay *H* to operate to the battery on the

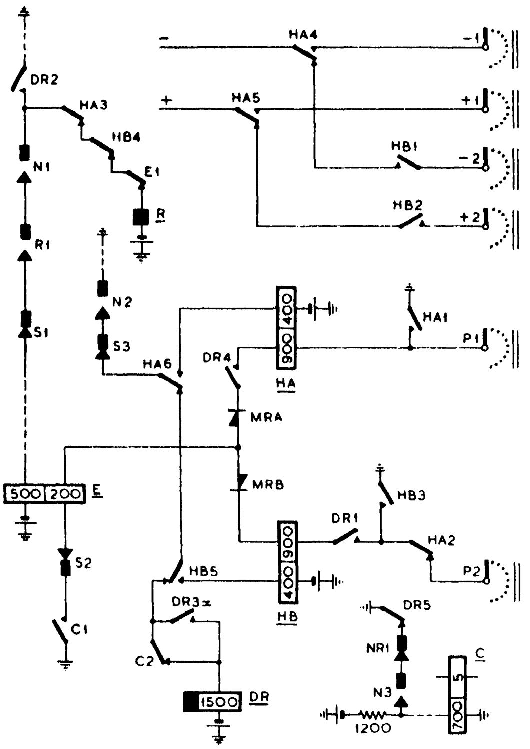


Fig. 277. Rotary Drive Combined with Dual Battery Testing Circuit

*P*1 bank of the free outlet. ***H*4** and ***H*5** disconnect the rotary drive circuit, whilst other contacts of the *H* relay switch through the negative and positive lines.

It has been seen that relay *G* operates at each step during rotary hunting. At each operation of *G*, contact ***G*2** disconnects the hold circuit of the *HS* relay but the latter holds for the period during which **G2** is operated due to the slug on the *HS* relay. When a free outlet is found, relay *G* holds to the current in the *P*1-wire, but shortly afterwards the *H* relay operates to re-establish the hold circuit for *HS* at ***H*5**. The release of *G* consequent upon the operation of ***H*2** and ***H*4**, however, again disconnects the hold circuit for *HS* at *G*2 so that the relay now releases after its period of lag. *HS*1 and *HS*4 finally disconnect the automatic drive circuit.

If no free line is found in a P.B.X. group, earth is encountered on the *P*2 bank when the wipers are stepped to the position corresponding to the last line of the group. This earth is extended via ***C*4** and the 2000 Ω resistor *YA* to hold the *G* relay. In due course the *HS* relay releases due to the disconnexion of its hold circuit at ***G*2**, and the *G* relay is now held from the earth at ***B*3** via ***N*1**, ***NR*2**, *HS*4, *E*2, and *H*4. Other contacts of the *G* relay return the engaged signal to the calling party. The 2000 Ω resistor *YA* is inserted to prevent the application of full earth potential to the *P*2 wiper during rotary hunting, i.e. when contacts ***R*1** close. If the resistor were not provided, the full earth would interfere with the rotary stepping circuit of any other selectors searching over the P.B.X. group at the same time.

The marking battery on the first *P*2 bank contact of a P.B.X. group must necessarily be of low resistance, so that, if necessary, two or more *HS* relays can operate at the same time to a common battery. In order to safeguard against the risk of fire, three resistors each of 200 Ω are placed in parallel and this combination is made to serve all the P.B.X.s in any one final selector group.

Rotary Drive with Dual Battery Testing. Occasionally, the battery testing circuit of Fig. 273 is required in conjunction with a rotary drive, under conditions somewhat similar to those of a 200-outlet group selector. These conditions are obtained, for example, in final selector circuits which are designed to cater for very large P.B.X. groups where the wipers are stepped by the subscriber's dial to the requisite level, and then automatic rotary hunting is required over that level. In such circumstances an availability of 20 outlets per level is often desirable which, in turn, necessitates a system of applying two testing relays to the *P* contacts at each rotary step.

A typical circuit element for use under such conditions is illustrated in Fig. 277. At the end of the vertical train, relay *C* releases and at *C*2 allows relay *DR* to operate. ***DR*3** provides a holding circuit for *DR* independent of *C*2. ***DR*2** completes the circuit for the rotary magnet, and, towards the end of the first rotary step, contacts ***R*1** close to complete the circuit for the *E* relay. ***E*1** now disconnects the rotary magnet circuit. This interaction of the *E* relay and the rotary magnet continues until such time as a free line is found or the wipers reach the 11th rotary step.

At the first rotary step, contacts ***NR*1** open and allow the *C* relay to re-operate by the removal of the earth from the 700 Ω winding. ***C*1** connects the 200 Ω coil of relay *E* to the 900 Ω windings of both relays *HA* and *HB*. If the first free outlet is on the

*P*1 bank, relay *HA* operates and relay *E* holds in series to arrest the rotary drive. If, on the other hand, the first free outlet occurs on the *P*2 bank, relay *HB* operates and the *E* relay is similarly held to stop the drive. The switching relay (*HA* or *HB*) is held after operation by contacts ***HA*6** or ***HB*5**, whilst the operation of one or other of these contacts disconnects the *DR* relay. The release of *DR*2 finally disconnects the rotary drive circuit, whilst *DR*1 and *DR*4 break the initial operate circuit of the *HA* and *HB* relays. Relay *E* now releases due to the break in this circuit. If it should so happen that free lines are encountered by both the *P*1 and *P*2 wipers, relays *HA* and *HB* both operate, but *HB* cannot hold due to the operation of ***HA*6**. ***HA*2** also disconnects the *P*2-wire to prevent the engaging of the *P*2-line whilst ***HB*3** is operated, i.e. until *C*1 restores due to the release of *DR*5. If all outlets on the level are engaged, the wipers rotate to the 11th rotary position when the ***S*1** and ***S*2** contacts prevent the re-operation of relay *E*. This arrests the rotary drive, and the magnet circuit is broken when *DR* releases due to the disconnexion of its circuit at ***S*3**.

The rectifiers *MRA* and *MRB* are provided to prevent the electrical conditions encountered by the *P*1 wiper being transmitted to the *P*2 wiper and vice versa. The rectifiers are so connected that both are in the conducting direction for the normal operating currents of the *HA* and *HB* relays, but a high impedance is introduced for any circulatory currents between the *P*1 and *P*2 wipers.

Automatic Search over a Number of Predetermined Levels. In certain circumstances a 2-motion selector is required to search for a free line over a number of predetermined levels. Such facilities are necessary, for example, on final selectors which are required to cater for P.B.X. groups of more than 20 lines. Fig. 278 shows a typical arrangement of a 2000 type circuit. With this element, provision is made for automatic search over the level selected by dialled impulses, and, if all lines on this level are engaged, the selector is released and then automatically continues the search over the second level. Provision is made for search over any number of levels, and the levels tested need not be in consecutive order. For example, if the wipers are initially stepped to the 5th level by the calling subscriber, automatic search can take place over this level, and, if all outlets are engaged, the switch can be made to release and step up to, say, the 3rd level. If all outlets on this level are also engaged, the switch will release and then automatically step to (say) the 7th level, and so on.

In this circuit the levels over which search is required, and the order in which the levels shall be tested, are determined by 4 discriminating relays *DW*, *DX*, *DY*, and *DZ*. Earth is applied to the 11th step contacts of the 4 line banks to operate various combinations of the discriminating relays in order to set up the correct conditions to provide search over the required levels.

The selectors to which this facility is applied are normally of the 200-line type, i.e. there are 4 line banks (− 1, + 1, − 2, + 2). Conditions are applied to the 11th step contacts of these banks in accordance with the following schedule:

Next Level over which Search is Required	11th Step Contacts Connected to Earth	Discriminating Relays Operated
0	+ 2	*DW*
9	− 2	*DX*
8	− 2 + 2	*DX* *DW*
7	− 1 + 2	*DZ* *DW*
6	− 1 − 2	*DZ* *DX*
5	− 1 − 2 + 2	*DZ* *DX* *DW*
4	+ 1 + 2	*DY* *DW*
3	+ 1 − 2	*DY* *DX*
2	+ 1 − 2 + 2	*DY* *DX* *DW*
1	+ 1	*DY*
Last level	− 1 + 1	*DZ* *DY*

If, for example, the outlets of level 5 have been tested and it is desired that the switch should next search over level 3, then the + 1 and − 2 11th step bank contacts are earthed in order to operate discriminating relays *DY* and *DX* respectively. When a complete search has been made over all the lines in a P.B.X. group, the 11th step bank contacts of the final level are earthed to operate discriminating relays *DZ* and *DY* in combination to prevent further hunting. The engaged signal is now returned to the calling party.

At the end of the vertical impulse train, relay *C*

releases due to the cessation of current pulses in its 5 Ω coil. *C*1 allows relay *DR* to operate and lock at ***DR*1**. ***DR*2** completes a circuit for the rotary magnet and, as the ***R*1** springs close, the same earth energizes relay *E*. ***E*1** now disconnects the rotary magnet circuit, and the interaction between the *E* relay and *R* magnet continues until a free line is found or until the wipers reach the 11th rotary position. At this point the ***S*2** springs close to for relay *RN* is broken at *N*3 and the relay releases. The release of *RN*3 completes the circuit for the vertical magnet via *DR*3, *DW*2, ***DX*4** and the vertical interrupter contacts (*V*1) to earth. The wiper carriage is therefore moved upwards under the action of this self-interrupted drive circuit. At the first vertical step, the ***N*2** contacts short-circuit the 700 Ω winding of *C*, but the *C* relay holds during vertical stepping due to the

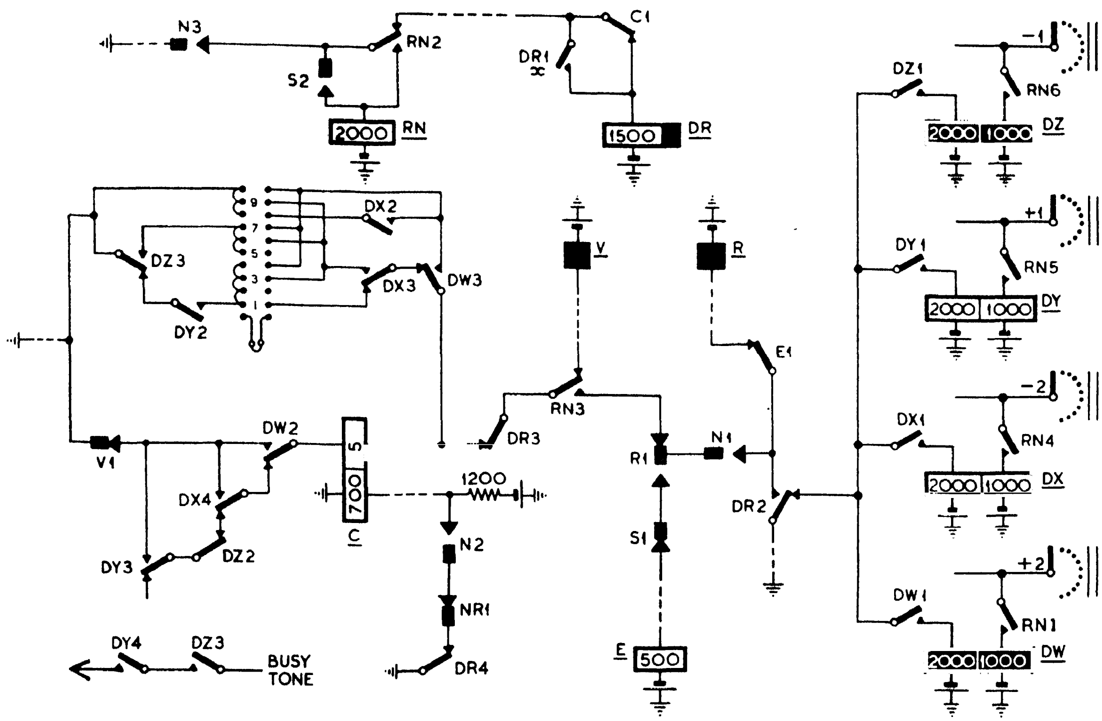


FIG. 278. METHOD OF OBTAINING AUTOMATIC SEARCH OVER A NUMBER OF PREDETERMINED LEVELS

operate relay *RN* which locks at ***RN*2**. The operation of ***RN*2** also disconnects the holding circuit for relay *DR* which at *DR*2 breaks the rotary drive circuit and completes the holding circuit for the discriminating relays. Assume, for example, that the next level over which search is required is level 9. Under these conditions the 11th step — 2 bank is connected to earth so that when the wipers reach the 11th rotary position the *DX* relay is operated via ***RN*4**. *DX* holds to the earth at *DR*2 via its own contact ***DX*1**. ***DX*4** now completes the rotary release circuit from earth through *V*1, ***DX*4**, *DW*2, the 5 Ω coil of the *C* relay, *DR*3, ***RN*3**, *R*1, ***N*1**, and *E*1. The rotary magnet and its interrupter contacts (*R*1) interact to drive the wipers out of the bank and the wiper carriage restores to normal.

When the normal position is reached, the circuit pulses of current in its 5 Ω winding. In due course the vertical marking wipers reach the desired level (level 9 in the example given). In this position, contact ***DX*3** provides a circuit from earth through the vertical marking bank and wipers to the vertical magnet side of the *C* relay. This path effectively short-circuits the vertical interrupter contacts *V*1 and so prevents further vertical drive. After a release period, the *C* relay releases and at *C*1 allows the *DR* relay to re-operate and lock. ***DR*3** disconnects the current through the vertical magnet, whilst ***DR*2** completes the rotary drive circuit and releases relay *DX*. Rotary stepping continues as described above until a free trunk is found or the 11th step is reached.

The process of discrimination and level selection is repeated as required for all the intermediate levels

of the P.B.X. group. If all outlets on the last level are engaged, the $-$ 1 and $+$ 1 banks are earthed to operate relays *DZ* and *DY*. Relay *RN* is held operated as before but the rotary release circuit is now broken at ***DZ*2**. The wipers therefore remain on the 11th step, and busy tone is returned to the calling party through other contacts of the *DY* and *DZ* relays.

The circuit element described above can be arranged to minimize the hunting time when search is to be made over very large groups of P.B.X. lines. It is possible, for instance, to arrange certain selectors in the final group to search over the levels in one particular order, but for other final selectors in the same group to have a different order of level testing. By this means the average time required to find a free line during busy periods can be appreciably reduced.

Search For and Switching To a Marked Line. It is interesting to see how the battery testing and automatic drive circuits already considered are applied to a 2-motion selector circuit which is required to search for and seize a given marked line in any level of the selector bank. These facilities are required, for example, in a subscriber's linefinder circuit employing 2-motion selectors. Fig. 279 shows the simplified driving and testing features of a 2000 type circuit. Each selector has a vertical marking bank, a testing bank and the usual $-$, $+$, and *P* banks. Ten 150 Ω battery connected resistors are provided to serve as the marking conditions for the ten vertical levels. These resistors are common to all selectors in the finder group. For the purpose of description, let it be assumed that a subscriber's line terminates on, say, the 6th contact of the 5th level and that the selector is required to search for and then switch this line to the next stage.

Relay *L* is operated when the lines are looped and at ***L*1** connects the 150 Ω marking battery (appropriate to level 5) to the start relay *ST*. ***ST*1** applies a temporary earth to the forward *P*-wire and in so doing provides a circuit for the operation of relay *H* on its 2000 Ω coil to the *R* magnet battery (via *NR*1 and *N*1). ***H*1** completes a circuit for the vertical magnet *V* via the vertical interrupter springs *V*1, *NR*3, ***H*1**, *VT*1 to the earth at ***ST*1**. At the first vertical step the initial operating circuit of *H* is broken at ***N*1**, but an alternative hold circuit is provided from battery at ***ST*2** via *VT*2, 10 Ω coil of *H*, ***H*3**, *NR*1, 2000 Ω coil of *H*, to the earth at ***ST*1**. When the wipers step to the marked level (level 5), relay *VT* operates to the 150 Ω battery extended to the vertical marking bank (*VMB*) by ***L*1**. ***VT*1** breaks the vertical magnet self-drive circuit, whilst ***VT*2** disconnects

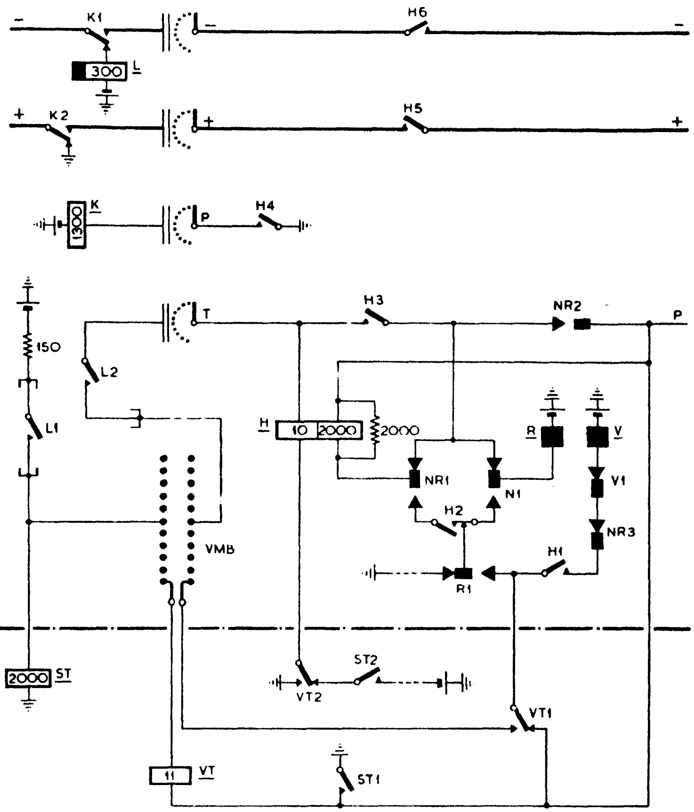


FIG. 279. METHOD OF SEARCHING FOR A MARKED LINE ON THE BANK OF A 2-MOTION SELECTOR

the holding circuit of *H* and replaces the battery potential on the 10 Ω coil by a full earth. *H* now releases after a short lag (due to the 2000 Ω shunt) and at *H*2 completes the rotary drive circuit through the interrupter contacts *R*1. At each rotary step, the operation of ***R*1** connects the *R* magnet battery via ***VT*1** to the vertical marking bank. When the wipers step to the marked contact (No. 6), this battery is extended via ***L*2** and the *T* bank and wiper to the 10 Ω coil of the *H* relay. The *R* magnet is held over this circuit to prevent further stepping until ***H*2** re-operates to cut the drive circuit. The *H* relay holds on its 2000 Ω coil from the *R* magnet battery via ***N*1**, ***H*2**, ***NR*1** to the earth on the *P*-wire and at ***H*5** and ***H*6** prepares for the switching of the $-$ and $+$ lines. ***H*4**

operates the K relay in the subscriber's circuit over the P wiper and bank. The K relay in turn disconnects the L relay (at **$K1$** and **$K2$**), and in due course the release of $L1$ allows ST and VT to restore. The speaking pair is now extended to the next switching stage and the linefinder is held to the earth on the P-wire (see Chapter VIII).

It should be noted that, due to the low resistance of the VT relay, the vertical marking bank contact is substantially at earth potential whilst search is proceeding over the selected level. This arrangement provides a guarding condition to prevent two selectors from hunting simultaneously over the same level. It also permits other switches in the same group to hunt for vertical markings on higher levels than the level on which a previous finder has been arrested.

The circuit shown in Fig. 279 provides facilities for finding one line in a group of 100. Often, there are economic advantages in grouping the lines in units of 200. This requirement necessitates the duplication of the wipers and banks and the introduction of a second switching relay. The principle of operation is the same in all other respects.

In practical linefinder circuits the components shown below the boundary line in Fig. 279 are often segregated from the linefinder and placed in a common control circuit which also performs the function of selecting the particular linefinder to be used. The circuit arrangements in such cases are somewhat more complex.

Automatic Search by Means of Relays. By the use of a chain of relays it is possible to design circuits which will search over a number of outlets, test for the engaged condition on each, and switch to the first free trunk. Fig. 280 shows a possible arrangement. It is assumed that contact $C1$ releases as a start signal for the automatic search. The earth from $C1$ operates relay SA through the chain of make-before-break contacts ($SB1$ to $SK1$). **$SA4$** applies the testing relay (T) to the P-wire of the first trunk but, if this outlet is engaged, the absence of battery on the P-wire prevents the operation of the T relay. **$SA2$** extends the earth from $T1$ to operate relay SB, whilst **$SB1$** provides a holding circuit before disconnecting relay SA. **$SB3$** removes the testing condition from the first outlet, and **$SB4$** applies the test relay to the second trunk. If this second trunk is also engaged, **$SB2$** operates SC whilst **$SC1$** disconnects relay SB. **$SC4$** tests the third trunk and the process continues until such time as battery potential is encountered on the P-wire. Relay T now operates and at **$T1$** prevents the operation of further relays.

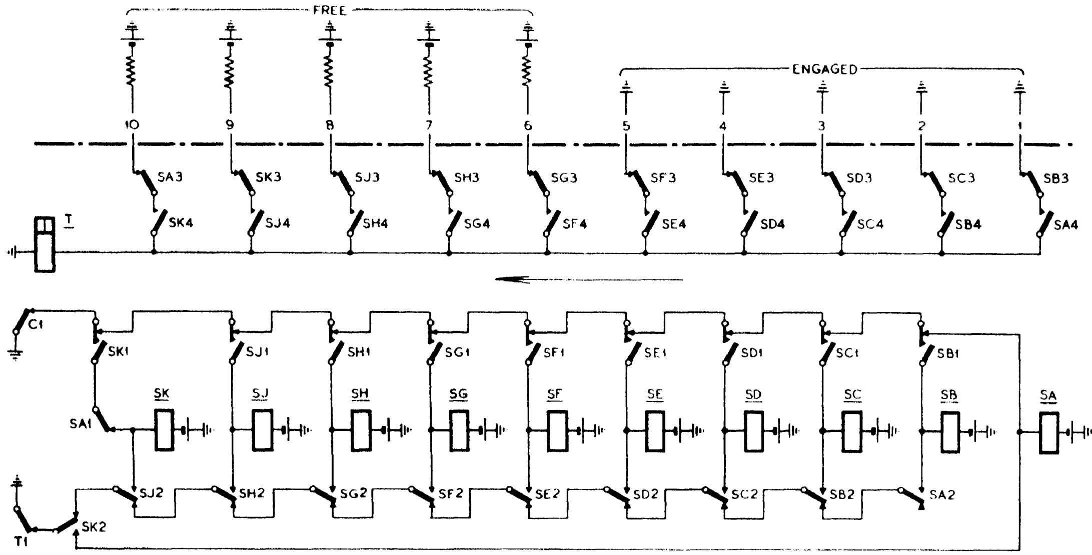


FIG. 280. A METHOD OF OBTAINING AUTOMATIC SEARCH BY MEANS OF A GROUP OF RELAYS

A circuit of this type can be made to provide a very high speed of search. In Fig. 280, it is clear that the testing relay is applied to the P-wire of each trunk for a period equal to the operate lag of the next relay in the chain. If the relays are designed to have an operate lag of, say, 10 msec, then it is clear that a speed of search of 100 trunks per second is obtained. The T relay must, of course, be designed so that its operate time is

materially shorter than the operate lag of the chain relays. For example, if the operate lag of relays *SA*, *SB*, etc., is 10 msec, then it is desirable that the test relay should operate in, say, 2 or 3 msec.

Wiper Switching. The principle of 200-line final selectors has been described in Chapter II. Such selectors are accessible from two levels of the preceding group selector stage, and the circuit is so arranged that, when the final selector is seized from one particular level, a wiper switching relay is operated to divert the call to the appropriate the *WS* relay at ***NR*1**, whilst other rotary off-normal contacts ***NR*2** short-circuit the initial operating winding of *WS* to remove the impedance of this winding from the speaking pair. It will be noted that wiper switching does not take place when the switch is seized, but is deferred until the end of the vertical impulse train. Similarly, the holding circuit for the *WS* relay is not established until the first rotary step. On release, the *WS* relay is held until the off-normal springs *N*1 open. It is of great importance that the switch should not be seized for a second call before the

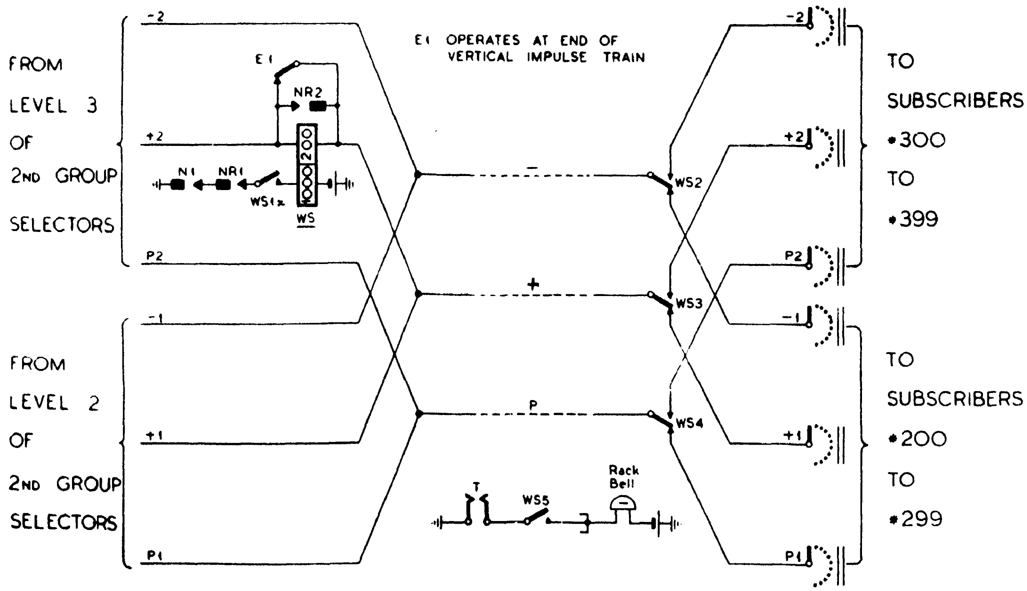


FIG. 281. WIPER SWITCHING ON 200-LINE FINAL SELECTORS

wipers and banks. Fig. 281 shows the standard circuit element used on 200-line final selectors. For purposes of illustration it is assumed that the final selector is connected to levels 2 and 3 of 2nd group selectors. If the final selector is seized from level 2, relay *WS* is not operated and the call is directed to the lower set of wipers (− 1, + 1, *P*1). If, however, the call originates from level 3 of the 2nd group selectors, relay *WS* must be operated to direct the call to the upper banks (− 2, + 2, *P*2).

The circuit is arranged so that relay *E* operates at the end of the vertical impulse train. Contact ***E*1** removes the short circuit from the 200 Ω winding of relay *WS* which operates in series with the subscriber's loop if the call is routed via level 3. The wipers are now rotated under the control of the final digit from the subscriber's dial, and, at the first rotary step, a hold circuit is provided for *WS* relay has released from a previous call or, if this is not obtainable, the circuit must be so arranged that *WS* can release before discrimination is necessary on the second call. It is the usual practice to provide *WS* contacts to prevent the re-seizure of a switch before the *WS* relay has fully released, but there is still a slight risk of re-seizure whilst the earth is momentarily removed from the *P*-wire during release. If a selector should be seized during this period, there is ample time for the *WS* relay to release between the opening of the *N*1 springs and the release of *E*1 at the end of the vertical train.

As in the case of 200-outlet group selectors, a test trunk bell is provided on the basis of one per rack. The short-circuiting of test jack springs *T* by the insertion of a plug allows the test trunk bell to operate if ***WS*5** is closed, i.e. if the call is switched to the upper bank.

EXERCISES VII

1. Explain concisely why "toggle" interrupters are used for the self-drive circuits of a modern 2-motion selector. Why is this type of interrupter not used with mechanisms of the uniselector type?

2. Describe, with the aid of simple diagrams, two types of earth testing circuit. What are the relative merits of the two circuits?

3. How does a "battery testing" circuit differ from a circuit of the "earth testing" type? Show how it is possible to minimize "dual switching" with a battery testing circuit, and explain the factors which must be considered in the design of such a circuit.

4. Why is it usual to utilize a battery testing circuit in a final selector? Show by means of a simple diagram how it is possible to combine automatic search with the testing circuit of a final selector.

5. A 2-motion group selector is required (*a*) to select a particular level under the control of dialled impulses, (*b*) not to release during the break periods of the impulses, and (*c*) to step into and hunt automatically for an idle trunk in the selected level. With reference to a simple diagram, explain how these functions are provided for in the circuit arrangements. (*C. & G. Telephone Exchange Systems I*, 1948.)

6 Describe the manner in which the wipers of a 200-line primary linefinder are directed to the calling subscriber's line. Illustrate your answer with a diagram of the circuit elements concerned. (*C. & G. Telephony, Grade II*, 1943.)

7. Describe, with the aid of a diagram, the operation of the testing and rotary stepping circuit elements in a 200-outlet group selector. Explain how it is possible, without exposing the relays to view, to determine which particular trunk has been selected. (*C. & G. Telephony, Grade II*, 1944.)

8. Making use of a diagram of the circuit elements concerned, describe the manner in which rotary hunting is controlled in a final selector designed to serve groups of lines to small private branch exchanges. (*C. & G. Telephony, Grade II*, 1943.)

9. With the aid of a diagram, explain how it is possible for the final selector levels, serving a large private branch exchange group of lines, to be tested for a free line in any predetermined sequence. (*C. & G. Telephone Exchange Systems II*, 1947.)

10. Two alternative designs for a telephone type relay have the following characteristics:

(i) Has a winding of 3000 turns and commences to operate when the total flux amounts to 4000 lines.

(ii) Has a winding of 5000 turns and commences to operate when the total flux reaches 3000 lines.

Assuming that the operating time is short compared with the time taken for the operating current to reach its steady value, determine (*a*) which design will afford the quicker operation, and (*b*) what will be the approximate times for operation to commence in a 50 V circuit containing no other inductance. (*C. & G. Telephone Exchange Systems III*, 1948.)

CHAPTER VIII

HOLDING, SPEAKING, AND RELEASE CIRCUITS

In the preceding chapters consideration has been given to the method of controlling automatic switch mechanisms by means of impulses from the subscriber's dial, the various means of obtaining automatic drive with selectors of the step-by-step type and the elements concerned in the switching of a call to a free or marked outlet. It is now necessary to examine the methods of holding the automatic switching circuits both during the establishment of a call and during the conversational period, the elements required for speech transmission and the methods of releasing or restoring the switching train at the end of a call.

Holding and Guarding. In all automatic switching circuits, provision must be made to *guard* an established call against intrusion by other searching selectors and to *hold* the mechanisms in their operated positions until the end of the call. Throughout the British Automatic Telephone System, the engaged condition of any switch or outlet is an earth on the *P*-wire, and this earth is also utilized to provide a circuit for the holding relay (or relays) of each selector in the train. At the end of a call, the removal of earth from the *P*-wire allows all mechanisms to restore to normal and removes the engaging condition from the *P*-wire.

In the absence of a telephonist, any connexion set up through automatic switching equipment is under the control of one or other of the two subscribers concerned. In the British Isles the calling subscriber (who pays for the call) controls both the setting up and the subsequent release of any purely automatic connexion. The only exception to this general rule is when a call is established through a manual switchboard and when it is desired that the operator should be able to hold the connexion even if the calling subscriber should replace his receiver. This facility is known as *manual hold* and is provided on all trunk switchboards and in a few other instances. It should be mentioned in passing that the manual hold facility can at present be provided only in circumstances where automatic fee registration is *not* required (see Chapter IX).

Whilst the principle of "calling party release" is universally applied in Great Britain, the automatic switching systems of certain other telephone administrations are designed to provide first party release, i.e. the connexion is broken down when the *first* of the two subscribers replaces his receiver. This principle is of particular application when the subscribers pay a fixed annual sum for telephone service and are not charged on a "message rate" basis. It is also possible to design circuits which remain established until the last party replaces his receiver (last party release) or, alternatively, the connexion can be placed under the control of the called subscriber (called party release). These two last principles are of very little practical application.

Backward and Forward Holding. Mention has already been made in Chapter V of the necessity for a relay bridged across the speaking pair and under the control of the cradle-switch contacts of the calling subscriber's instrument. The circuit is so arranged that this relay is operated for so long as the calling subscriber's receiver is off the rest, whilst contacts of the line relay control a slugged relief relay (*B*), the contacts of which are used to prepare the selector for use and to provide holding and guarding conditions to the *P*-wire. It is theoretically possible to provide for the holding and guarding of each selector of a switching train by the provision of separate line relays in each selector circuit. With this method there would be a number of relays bridging the speaking pair on every call, and the resulting transmission loss would probably be intolerable. Apart from transmission requirements, however, individual holding and release of each selector in a switching train would introduce a number of major difficulties in respect of dialling and of unguarded periods during the release of the call.

For the above reasons, the number of bridging relays across the speaking pair during the conversational period is reduced to a minimum. The ideal condition would be to have one relay per call for impulsing and holding and which also serves to supply transmitter feeding current to the calling subscriber. These ideal conditions can often be obtained on purely local calls (i.e. on calls from one subscriber to another on the same exchange). On junction calls, however, it is usually uneconomical to provide a 3-wire junction to cater for the speaking pair and the *P*-wire, and in practice it is necessary to have a bridging relay across the speaking pair at each exchange to maintain the earth on the *P*-wire. This principle is modified to some extent by the necessity of locating the

transmission bridge in the most economical position and also by the requirements of impulse repetition.

The bridging relay can theoretically be placed in any one of the selector circuits which form the complete switching train. The relay can, for instance, be placed in the subscriber's line circuit, in any of the circuits of the intermediate switches or in the final selector circuit. If the bridging relay is placed in the first link of a connexion, then it is clear that the remaining switches in the same exchange are held by the earth applied to the first switching point which is extended forward over the P-wire.

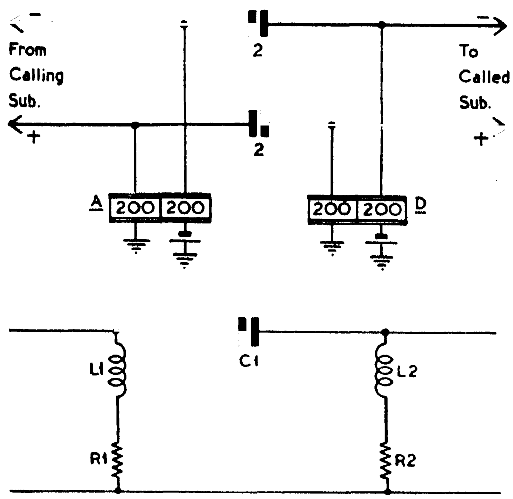


FIG. 282. CAPACITOR-IMPEDANCE TRANSMISSION BRIDGE

Conversely, if the bridging relay is located in the final selector, then the earth is returned backwards on the P-wire to hold all the preceding switches of the train. There are, therefore, two fundamental methods of applying the holding condition, i.e. *forward holding* and *backward holding*. Sometimes it is expedient to locate the bridging relay in one of the intermediate links of a switching train. In these circumstances the holding conditions are a combination of backward and forward holding.

Transmission Bridges. The transmission bridges of an automatic system are required to meet conditions much more onerous than in a manual switching system. In the latter, the transmission bridge is required primarily to supply current for the energization of the carbon transmitters in the subscribers' instruments. If, as is usual, separate feeds are supplied for the calling and called subscribers, then it becomes necessary to segregate the speaking pair from a d.c. point of view, but to provide a ready path through the bridge for alternating currents of speech frequency. Apart from the transmission requirements, the impedance coils of capacitor type transmission bridges are sometimes used as relays in order to repeat the supervisory conditions from the subscriber's loop to the indicators or lamps in the cord circuit. In an automatic switching system, the transmission bridge elements must, in a number of cases, also perform as impulse accepting circuits. This requirement must be co-ordinated with the transmission and supervisory functions, so that very careful design is necessary.

Up to the present time, the transmission bridges in automatic selector circuits have been mainly of the Stone (or capacitor-impedance) type. A typical bridge designed for use with the standard 50 V battery of automatic systems is illustrated in Fig. 282. The transmitter current is supplied to the calling subscriber through a high impedance relay (A) which has two balanced windings each of 200 Ω. The transmitter feeding current to the called subscriber is fed through a similar relay (D) on the other side of the bridge. The two lines are linked for speech currents by the 2 μF capacitors in series with the — and + lines.

The lower part of Fig. 282 shows the equivalent electrical circuit of the transmission bridge. (The inherent resistance of the capacitors and the self-capacitance of the relay windings have been ignored, since their effect is small at the ordinary frequencies of speech.) The bridge is in essence a high-pass filter. The shunt impedances are made up of the inductance and resistance of the transmission bridge relays ($L1$, $L2$, and $R1$, $R2$). The reactance of these inductive elements increases with frequency (i.e. $X = \omega L$), and hence the shunt loss is greatest at low frequencies with a progressively decreasing loss as the frequency is increased. This effect is further increased by the reactance of the series line capacitor, which decreases with rise of frequency (i.e. $X = 1/(\omega C)$).

From a signalling point of view, the high attenuation of the bridge at low frequencies is highly desirable. Impulsing can be considered as a fundamental frequency of 10 c/s with a number of multiple frequency harmonics of progressively less magnitude. The fundamental frequency and the more important first order harmonics are effectively suppressed by the bridge. Unfortunately the shunt impedance elements are ineffective for longitudinal voltage surges, and the capacitor-impedance type of bridge provides a ready transmission path for such surges. It is this fact which introduces a number of difficulties when capacitor type bridges are used at impulse repetition points (see Chapter VI).

Although the transformer type of bridge has not so far been used to any great extent in automatic

telephone circuits, it appears possible that there will be increasing use of this type of bridge in the future—especially at impulse repetition points where it has special merits. Fig. 283 shows the general arrangements of such a transformer bridge. As before, transmitter feeding current to the calling and called subscribers is supplied through relays A and D respectively, but these relays can now be of low impedance since they do not form part of the speech transmission circuit. Speech coupling from one side of the bridge to the other is provided by the four windings of the bridge transformer—segregation for signalling purposes being obtained by the insertion of 2 μF capacitors at the centre points. The lower part of Fig. 283 shows the approximate equivalent circuit of the transformer type bridge. (As in the previous case, the self-capacitance of the windings and the inherent resistance of the capacitors have been omitted for simplicity.) The shunt element now consists of an inductance $L1$ in parallel with a resistor $R1$. $L1$ represents the magnetizing current loss of the

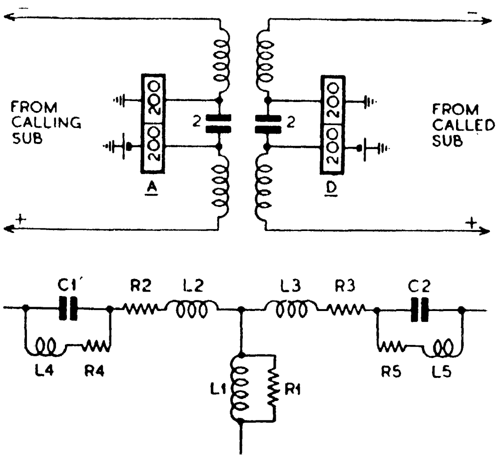


FIG. 283. TRANSFORMER TYPE BRIDGE

transformer, whilst $R1$ is the circuit equivalent of the eddy current and hysteresis losses in the transformer. $L2$ and $L3$ represent the "free" inductance of the transformer windings, which results from flux leakage, whilst $R2$ and $R3$ provide for the ohmic resistance loss of the transformer windings.

The capacitances $C1$ and $C2$ are, of course, the series line capacitors (each of 2 μF), whilst the signalling relays (A and D) can be represented by

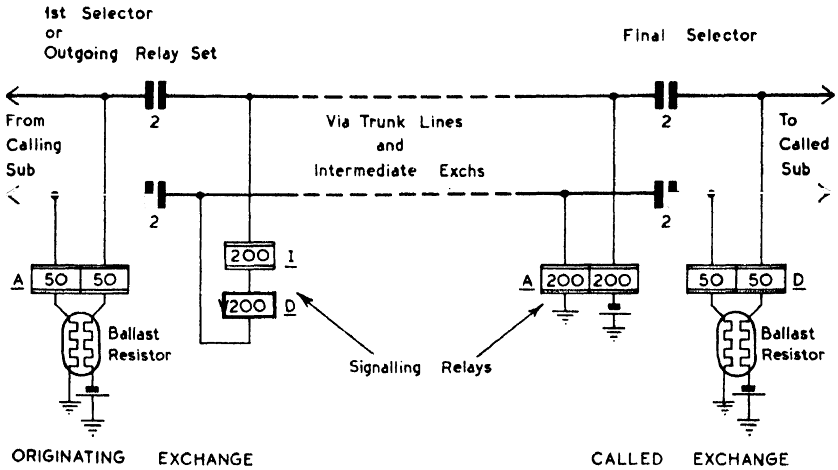


FIG. 284. USE OF BALLAST RESISTOR

$L4$, $R4$ and $L5$, $R5$, each in parallel with their respective capacitors.

By careful transformer design, it is possible to provide a bridge which has a minimum and reasonably uniform transmission loss over the range of speech frequencies (say, 300–3400 c/s), but which has a comparatively rapid cut-off below about 300 c/s. Such a design is quite satisfactory from a speech transmission point of view, and at the same time provides the maximum attenuation to signalling currents of low frequency. Longitudinal surges of equal amplitude are effectively suppressed by the differential action of the two windings on each side of the transformer (i.e. current surges in the same direction along the − and + lines flow through the transformer windings in such a direction that there is no induced e.m.f. in the secondary circuit).

Ballast Resistors. In recent years ballast resistors have been introduced to increase the volume efficiency on long subscribers' lines. The ballast resistor (see Volume I) when used in conjunction with an impedance element of 50 + 50 Ω gives a larger transmitter current on lines of high resistance but, at the same time, prevents excessive current when the transmission bridge is connected to a line of negligible resistance. With a modern ASTIC telephone, the introduction of ballast resistors somewhat increases the maximum line resistance through which satisfactory transmission can be obtained. At the same time it should be noted that, although the ballast resistor gives some gain of *volume* efficiency on long lines, its use does

not necessarily increase the *articulation* efficiency of the circuit. The volume efficiency on local calls in an automatic system is usually adequate (even with high resistance lines), and the expense of ballast resistors is scarcely justified for such calls. Ballast resistors are, on the other hand, of particular value on trunk calls where the volume levels are lower. It is the standard practice to introduce

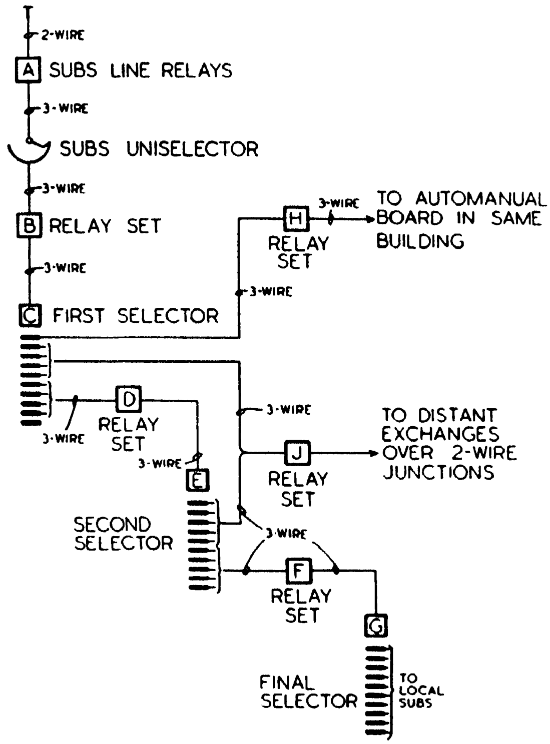


FIG. 285. COMPOSITE TRUNKING DIAGRAM SHOWING POSSIBLE ALTERNATIVE POSITIONS OF TRANSMISSION BRIDGE

ballast resistors only on those transmission bridge elements which may supply transmitter current to a subscriber when a long-distance call has been set up.

Fig. 284 shows typical applications of the ballast resistor. When there is a transmission bridge in the final selector, the called side of the bridge is utilized for incoming trunk calls and hence includes a ballast resistor. Similarly, when the transmission bridge is in the first selector, the calling side of the bridge supplies transmitter current to the originating subscriber on outgoing trunk calls, and hence this element is also fitted with a ballast resistor. The relay on the calling side of the final selector bridge is used only as the transmitter feeding element for local calls and is therefore of the ordinary $200 + 200\ \Omega$ type. All other bridging relays are for signalling purposes only. If, as in a non-director exchange, there is no transmission bridge in the first selector, then the bridging element in the trunk exchange relay set is of the ballast resistor type since this relay is required to furnish transmitter current to the calling subscriber for trunk calls.

Position of Transmission Bridge. The theoretical location of the transmission bridge (or bridges) is largely determined by economic considerations, but the necessity for standardization and for a uniform practice is often the deciding factor in the design of an exchange. Fig. 285 is a composite diagram, prepared to show a variety of switching conditions.

If we consider a local call, it is clear that the transmission bridge could be located at any of the points A to G. In no circumstances would it be economical to locate the transmission bridge in the subscriber's line circuit (position A), owing to the very large number of such circuits and the comparatively small volume of traffic carried by each. The number of 1st, intermediate and final selectors is determined by the volume of traffic but, since the 1st selectors are arranged in one large common group, the average traffic per switch is greater than that of the selectors in subsequent stages. (At the final selector stage, for example, the total exchange traffic is divided into a large number of separate groups, and each small group of final selectors is worked considerably less efficiently than the switches in the very much larger group of 1st selectors.) The advantage is most marked when the exchange is fully equipped (i.e. when all the 1st selector levels are in use) but it is, nevertheless, appreciable even in an average partly equipped exchange. It appears, therefore, that, in any exchange where the traffic is predominantly local, the most economical position for the transmission bridge would be in the 1st selector.

The disadvantage of this scheme lies in the fact that it necessitates the repetition of all the impulse trains to step the subsequent selectors in the switching train. In practice, if the bulk of the traffic is local, it is usually preferable to locate the transmission bridge in the final selector rather than to provide an impulse repetition bridge in the 1st selector, with the consequent circuit complications. In these circumstances, the train of switches is held backwards from the final selector. It is, of course, not necessary that the transmission bridge should form part of any selector circuit. It is quite practicable to provide the transmission bridge and the switching train holding relays in specially designed relay sets, which can be inserted in the

trunks between successive stages of selection. Instead, for example, of locating the transmission bridge in the final selector (G), a special relay set (F) could be provided in the trunks between the 2nd selectors and the final selectors. There are two main advantages from such an arrangement: In the first place all the selectors (1st, 2nd, or final) can be of substantially the same design with the consequent advantages of interchangeability. Secondly, it provides a trunking scheme which is more flexible, i.e. the transmission bridges in any particular exchange can easily be located in the position which gives the greatest economic advantage.

Against these merits must be weighed the additional cost of the subsidiary transmission bridge relay set. Whilst the total number of relays is not increased by locating them in a separate relay set, there is the cost of the mounting plate, racks and wiring, which can be avoided by placing the bridge on the selector mounting plate.

So far we have been assuming that the bulk of the traffic of an exchange is routed to local final selectors. In some exchanges—particularly in congested city areas—quite a high percentage of the total originated traffic is passed over outgoing junctions to other exchanges. These junctions can be trunked from appropriate levels of the 1st, 2nd, or subsequent selectors, and, if the exchange is designed to provide backward holding from final selectors, it is necessary to provide a special relay set (J) on each outgoing junction in order to hold the preceding switches. If there is a large number of outgoing junctions from selector levels, it may be more economical to locate the main transmission bridge in the 1st selector, thereby avoiding the provision of an appreciable quantity of separate relay sets on the outgoing junction routes. The 1st selector would then provide forward holding conditions for the control of all calls —both local and junction.

It has been assumed that the junctions are outgoing to other automatic exchanges. If the bulk of the junction traffic is to manual exchanges, then it may still be necessary to provide a relay set at the outgoing end of the junction to convert from the loop dialling conditions to the C.B. signalling requirements of the junction. In these circumstances the above reasoning does not apply.

It is possible to design an exchange trunking scheme so that the junctions are concentrated into certain groups of, say, 2nd selectors, whilst the final selector groups are trunked from the banks of other groups of 2nd selectors. If such a trunking scheme could be adopted, some economies could be effected by providing relay sets in position D, i.e. on the trunks to those 2nd selector groups which serve only outgoing junctions. The principle is the same as before. The traffic on the incoming side of the 2nd selectors is concentrated into large units, whereas the traffic on each individual outgoing junction is necessarily smaller. A given number of relay sets in position D will carry appreciably more traffic than the same number of relay sets placed directly on the outgoing junctions.

If the automanual switchboard is in the same building as the automatic plant, there is no objection to extending the 3-wire circuit right up to the termination of the manual board. It is nevertheless necessary to provide a relay set (H) on all such circuits in order to convert to the appropriate signalling conditions required on the manual board. Once a relay set has been provided for this purpose, then this same relay set can provide the necessary conditions to hold all preceding switches. Manual board circuits do not usually, therefore, enter into the economic considerations relating to the position of the transmission bridges in the main switching train.

The automatic telephone system in Great Britain has been standardized on the basis of two forms of equipment, i.e. *non-director* equipment for use in provincial areas generally, and *director* type equipment for use in exchanges of large city areas. Generally speaking, the proportion of outgoing junction traffic is comparatively small in non-director exchanges; on the other hand, in most director exchanges it is not unusual for as much as 60 or 70 per cent of the total traffic to be routed over outgoing junctions. The Post Office have, therefore, adopted the general principle of backward holding in non-director exchanges (i.e. the bridge is located in the final selector), whilst forward holding (from the 1st selector) is standard for exchanges of the director type. The subscriber's uniselector or linefinder is, in all cases, held backwards from a succeeding selector.

Whilst these arrangements may not provide the most economical scheme in certain exceptional cases, they possess the great advantage of uniformity.

Backward Holding (Pre-2000 Type Circuits). The principle of backward holding has already been considered, and it remains to examine the circuit elements concerned in the holding and guarding of a connexion as the call is established stage by stage. It is clear from the principle of backward holding that temporary holding conditions must be provided during the setting up of a call until the final selector is seized and the permanent holding earth is returned on the P-wire. Fig. 286 shows typical circuit elements of a pre-2000 type switching train

consisting of a subscriber's uniselector, 1st and 2nd group selectors and a final selector. The switching circuit of the subscriber's uniselector and of the group selectors is the earth testing circuit already considered in Figs. 255 and 257, whilst the switching circuit of the final selector is of the battery testing type shown in Fig. 262. These circuits have been considerably simplified in Fig. 286 for clarity.

and holding earth to the incoming *P*-wire. Relay *L* is made slow to release so that, on the operation of ***K*1** and ***K*2**, contact ***L*1** maintains a guarding and holding earth on the *P*-wire for a sufficient time to allow contact ***B*1** to take over its functions. The release lag of *L* must therefore be greater than the operate lag of relay *A* plus the operate lag of *B*. In actual practice, the *L* relay is fitted with an

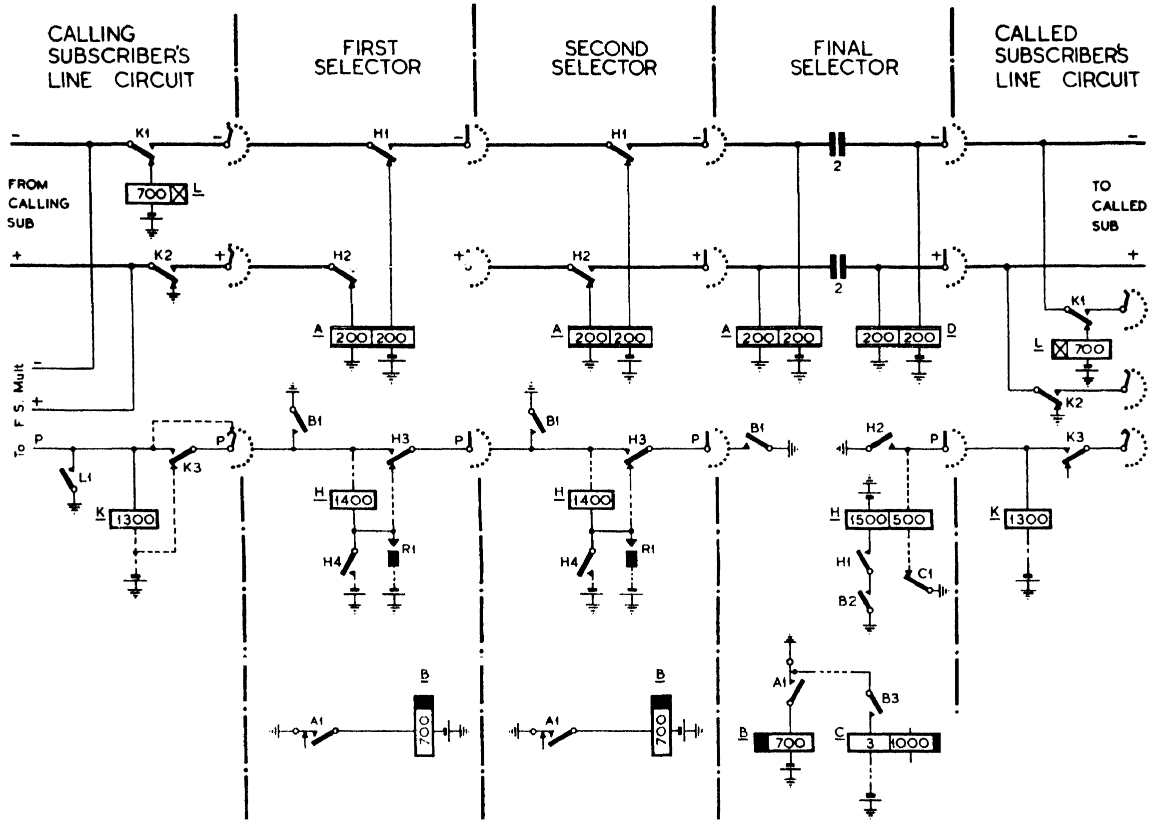


FIG. 286. BACKWARD HOLDING CONDITIONS IN A 4-DIGIT EXCHANGE
(Pre-2000 type circuits)

When the calling subscriber lifts his receiver, relay *L* operates to the loop at the subscriber's telephone. Contact ***L*1** immediately applies a guarding earth to the *P*-wire of the final selector multiple, thereby preventing intrusion by any party attempting to call the subscriber. Other contacts (not shown) of the *L* relay cause the uniselector to search for a free 1st selector, and, when a disengaged outlet is found, relay *K* operates due to the absence of earth on the *P* bank contact. *K* holds to the earth at ***L*1** and arrests the rotary search. ***K*1** and ***K*2** now disconnect the *L* relay and extend the call to the *A* relay of the 1st selector. ***A*1** operates *B* and ***B*1** in turn applies a guarding

armature-end slug so that, in the event of the uniselector finding a free outlet on the first step, the *L* relay will be fully fluxed before it is disconnected by ***K*1** and ***K*2**. This is important in order to ensure the requisite release lag to cover the operation of relays *A* and *B* in the 1st selector.

The *A* relay of the 1st selector responds to the impulses from the subscriber's dial and the switch hunts over the selected level. At each rotary step, contacts ***R*1** operate and apply battery to the *H* relay. If there is earth on the *P* bank, i.e. if the outlet is engaged, the *H* relay is short-circuited and stepping continues. In due course, the *P* wiper encounters a disengaged trunk to a 2nd selector,

and the absence of earth on the P-wire allows relay H to operate. **$H4$** provides a holding circuit for H under the control of the earth on the P-wire from **$B1$**. **$H1$** and **$H2$** now extend the call to the A relay of the 2nd selector, where **$A1$** operates B, and **$B1$** applies a guarding earth to the P-wire in readiness for the release of $B1$ in the 1st selector. It will be noted that the requisite period of overlap is now obtained from the release lag of relay B in the 1st selector. The release lag of B must, therefore, be sufficient to cover the operate time of relay A plus that of relay B in the 2nd selector.

The switching train so far established is now held backwards from the **$B1$** contact in the 2nd selector, and all bridging apparatus has been removed from the speaking pair except the one impulsing accepting relay in the 2nd selector circuit. In due course, the 2nd selector is stepped by the subscriber to the required level, rotary hunting takes place and eventually relay H switches to a disengaged final selector. The operation of **$H1$** and **$H2$** extends the call to the A relay of the final selector, and again **$A1$** operates B. **$B1$** of the final selector now applies earth to the P-wire, and, when the B relay of the 2nd selector releases, the temporary earth applied at **$B1$** in the 2nd selector is removed. The whole of the switching train is now held from the earth applied to the P-wire by the **$B1$** contact in the final selector.

The vertical and rotary movements of the final selector are controlled by impulses from the calling subscriber, and if the required line is disengaged relay H operates to the battery via the K relay in the called subscriber's line circuit. The K relay itself operates in series with the H relay and at **$K1$** and **$K2$** removes the L relay and earth from the speaking pair. Relay H locks under the control of relay B at **$H1$**, whilst **$H2$** applies a full earth to guard and engage the called subscriber's line.

During the conversational period, transmitter feeding current is supplied to the calling subscriber through relay A, whilst relay D supplies the current to the called subscriber. The whole connexion is held by the operation of relay A in the final selector which, at **$A1$**, holds B. When the calling subscriber replaces his receiver at the end of the call, the cessation of current in the loop allows relay A to release. $A1$ disconnects the circuit of relay B which releases after a period of lag. $B1$ removes the guarding and holding earth from the P-wire backwards and thereby allows relays H in the 1st and 2nd selectors and relay K in the subscriber's uniselector circuit to release. These relays in turn complete the release circuit for the selectors. $B2$ disconnects the holding circuit for relay H in the final selector, and $H2$ removes the holding earth from the forward P-wire, thereby allowing relay K in the called subscriber's line circuit to restore. Other contacts of the H relay complete the release circuit of the final selector. It should be noted that, whilst the main switching train is held backwards from the final selector, the called subscriber's line circuit is held engaged by a forward holding condition from the same selector.

Backward Holding (2000 Type Circuits). The circuit details of the guarding and holding features of the 2000 type selector train are somewhat more complicated due to the use of the pre-operated testing relay on group selectors of the 2000 type. It has already been seen that such testing circuits require the use of a second relay to carry out the main switching function and, in practice, the C relay (which is primarily required for impulsing) is utilized for the switching operation. It is this dual use of the C relay which somewhat complicates the circuit arrangements.

The appropriate elements are shown in Fig. 287. Only one group selector has been shown for simplicity, but it will be realized that the circuit arrangements of the intermediate selectors are exactly the same as those shown in Fig. 287 for the 1st selector. When the calling subscriber lifts his receiver, relay L is operated as before and **$L1$** applies a guarding earth to the final selector multiple. The association of the calling subscriber's line with the 1st selector is exactly the same as in the pre-2000 type circuit already described. When the calling line is extended to the 1st selector, relay A operates from the subscriber's loop and at **$A1$** operates B. **$B1$** applies a guarding earth backwards on the P-wire to hold the K relay in the subscriber's line circuit in readiness for the release of $L1$ (after the slow-to-release period of relay L). **$B3$** pre-operates relay C in readiness for impulsing, and at the first vertical step the closure of the off-normal springs (**$N1$**) allows relay H to operate on its 500 Ω winding from the earth at **$C1$**. At the end of the vertical train, relay C releases due to the cessation of current pulses through its 5 Ω coil, but relay H remains operated via its own contact (**$H1$**) and the rotary interrupter contacts (**$R1$**). It will be noted that, during the initial operation of relay C, the circuit of the A relay is maintained by the rotary off-normal contacts $NR1$ and $NR2$.

At the first rotary step, contacts **$NR1$** and **$NR2$** open to place the A relay under the control of contacts $C3$ and $C4$. Contacts **$NR3$** prepare a circuit for the holding of the C relay at a later stage. At each rotary step, the holding circuit of relay H is interrupted at contacts **$R1$**. If the wipers are at this time standing on an engaged outlet, the H relay is maintained by the earth on the P-wire

which provides a holding current in the 2000 Ω coil of H via **H2**. When a free outlet is found, H releases due to the absence of earth on the P-wire, and $H3$ completes a circuit for the C relay over both coils in series. C locks via **C2** and **NR3** independently of **H3**, whilst contact **C5** extends the P-wire until a replacing earth is returned from the next selector. The same sequence of operations occurs at each group selector stage. Ultimately the final selector is seized, and the operation of relay A in this circuit operates relays B and C. Relay C releases at the end of the vertical train, is re-

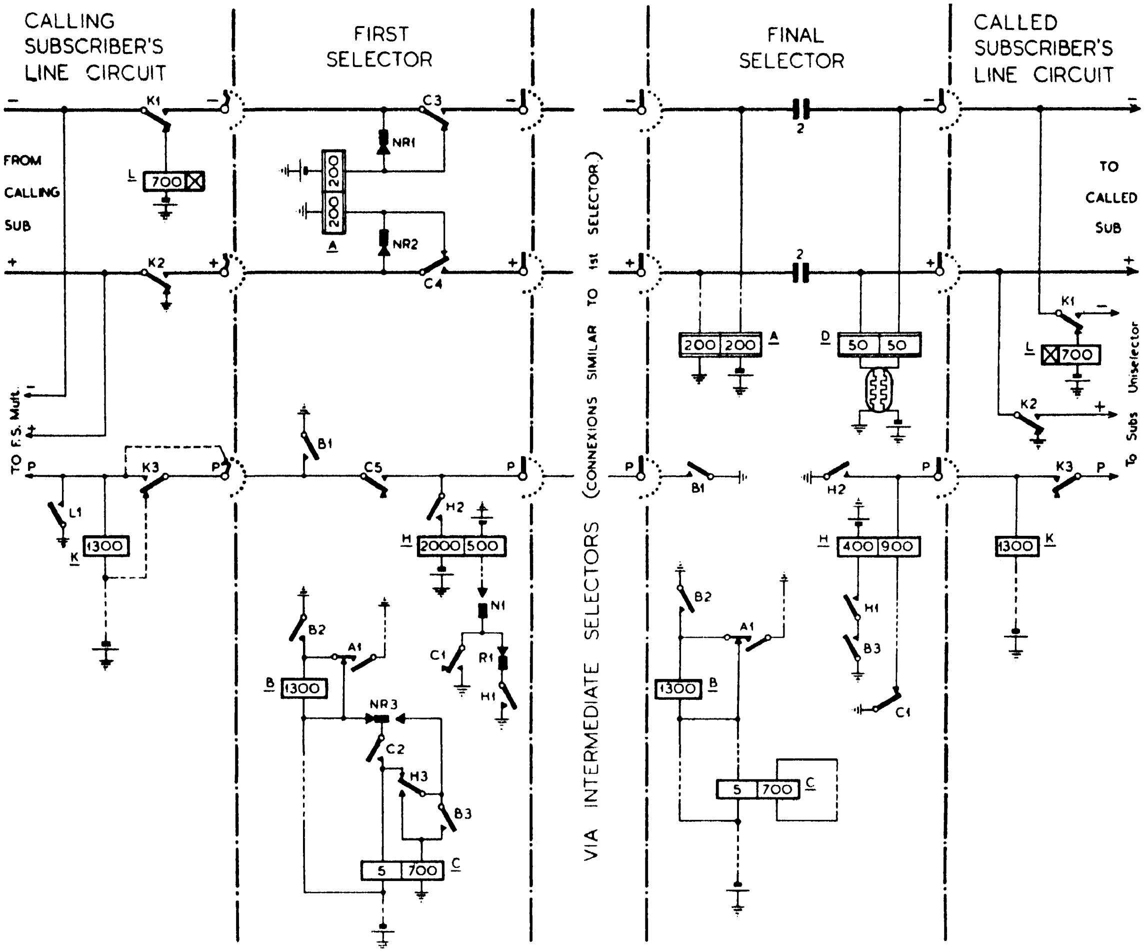


FIG. 287. BACKWARD HOLDING CONDITIONS WITH 2000 TYPE CIRCUITS

earth at **B1** to guard the seized outlet. **C3** and **C4** switch through the speaking pair to the next selector, whilst **C1** re-operates relay H on its 500 Ω coil. Relay A in the 1st selector is now disconnected and at $A1$ releases B. The release of $B3$ in turn places the holding circuit of relay C under the control of **H3**. The whole selector is now held by the energization of relay H from the earth on the P-wire.

Contact $A1$ on release short-circuits the B relay, and the resultant lag of the latter is sufficient to maintain the holding and guarding earth on the operated, and again releases at the end of the rotary train. The restoration of $C1$ now applies the 900 Ω testing coil of H to the P wiper, and, if the called subscriber's line is disengaged, H operates and locks via **H1**. **H2** applies a guarding earth forward to hold the K relay in the called subscriber's line circuit and to guard the line against intrusion. Relays A and B are held for the duration of the call, **B1** providing the required earth to hold all previous switches backwards, whilst **B3** maintains the H relay, thereby guarding (at **H2**) the called subscriber's line.

When the calling subscriber replaces his receiver, $A1$ releases B, and $B1$, by removing the earth from the P-wire, allows all previous selectors to release. $B3$ releases H, and $H2$ allows the called subscriber's line circuit to restore to normal. The transmission bridge shown in Fig. 287 is of the type usually provided on final selectors of the 2000 type, i.e. the A relay is of the normal $200 + 200\ \Omega$ type, whilst a ballast resistor in conjunction with a $50 + 50\ \Omega$ relay is provided on the called side of the bridge.

Backward Holding—Junction Calls. It has already been seen that the absence of a third conductor in a junction circuit necessitates a separate holding circuit at each exchange through which the call passes. Fig. 288 shows the circuit elements involved when a system of backward holding is employed. The subscriber's uniselector circuit and the various group selectors at the originating exchange are held backwards by an earth applied to the P-wire from an outgoing junction relay set (auto-to-auto relay set). The relay set also provides (to the outgoing junction) a loop of comparatively low ohmic resistance but of high impedance to speech currents. This loop is controlled by contact **$A1$** which, in turn, is dependent upon the operation of relay A in the auto-to-auto relay set under the control of the calling subscriber's cradle-switch. At the terminating exchange, the loop from the auto-to-auto relay set controls the setting up of the several selectors in the train, and during the conversational period the complete switching train at the incoming exchange is held by the energization of relay A in the final selector from the loop extended over the junction. Contact **$A1$** operates B and **$B1$** in turn holds all switches at the terminating exchange backwards.

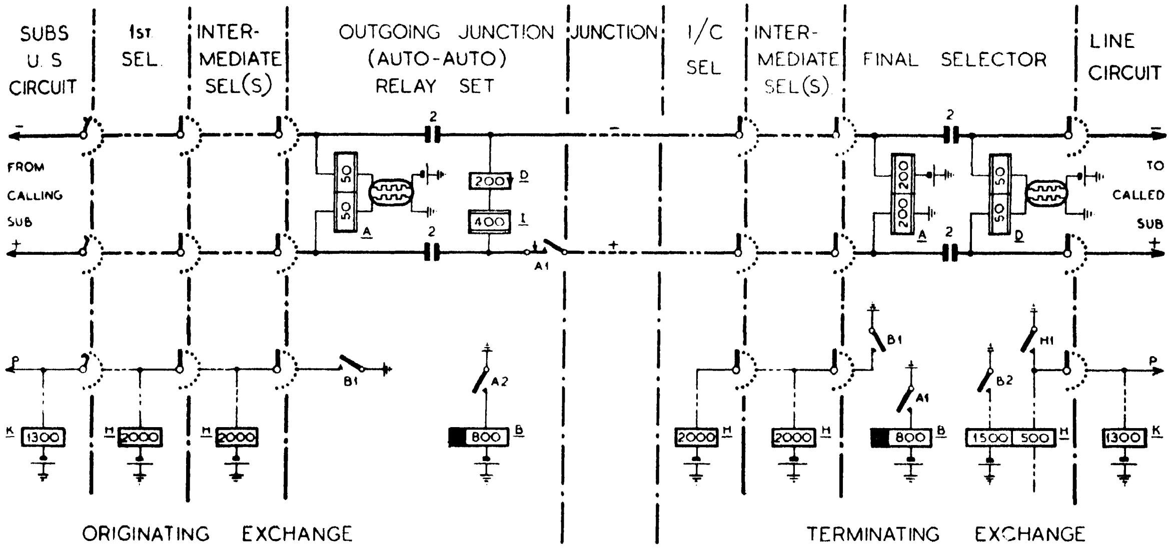


FIG. 288. BACKWARD HOLDING CONDITIONS ON JUNCTION CALLS

Forward Holding. In some cases (notably in the Director System where a high percentage of calls is routed over outgoing junctions) the calling subscriber's transmission bridge is located in the 1st selector and all switches in the outgoing exchange are held forward from this bridge. Fig. 289 shows the circuit conditions existing on an established connexion routed through a 1st selector, two intermediate selectors and a final selector. Relay A of the 1st selector is held to the loop formed by the calling subscriber's telephone and at **$A1$** establishes a loop forward to hold the A relay of the final selector. **$A2$** (1st selector) operates relay B and **$B1$** operates a relief relay BA. Contact **$BA1$** provides a holding and guarding earth to hold the subscriber's uniselector circuit and to guard the uniselector outlet against intrusion. **$BA2$** holds relay H, whilst a contact of the latter (**$H1$**) provides a holding and guarding earth forward to the remaining selectors in the train. The H relays of the intermediate selectors are held to the earth at **$H1$**, but the final selector itself is held by its own B relay which, under the control of relay A, maintains the holding circuit of relay H at **$B2$**. Contact **$H1$** holds and guards the line circuit of the called subscriber.

It will be seen that a contact (**$B1$**) applies an earth on the P-wire backwards from the final selector. It would therefore appear at first sight that the main switching train is held backward

from the final selector as well as forward from the 1st selector. Further examination will, however, reveal that the release of the intermediate selectors is controlled by the 1st selector, i.e. that forward holding conditions do in fact exist. Where the transmission bridge is located in the 1st selector it is, as will be seen later, very desirable to prolong the guarding condition from the 1st selector in order to prevent the re-seizure of a junction before the distant selectors have had time to release from the previous call. It is for this reason that two slow-to-release holding relays (B and BA) are provided in the 1st selector. When the calling subscriber replaces his receiver, relay A releases and $A2$ breaks the circuit for relay B, and after a lag of some 300 msec $B1$ disconnects BA and there is a further lag of similar duration before contacts $BA1$ and $BA2$ remove the holding conditions. There is therefore a minimum lag of, say, 600 msec before the holding earth is removed at contact $H1$. The holding loop provided by **A1** in the 1st selector is, however, broken within a few milliseconds of the termination of the call. The final selector A relay releases after a further short lag, and the earth returned on the P-wire is removed when relay B (final selector) releases some 250–300 msec after the replacement of the receiver. It is clear, therefore, that on the release of a call the intermediate switches will be held by **H1** after $B1$ has restored.

The necessity for contact $B1$ in the final selector may be questioned. Whilst it is true to say that the contact has no real function on a straightforward local connexion such as that described above, there are nevertheless some circumstances where it may be required. If, for example, the final selector is accessible from incoming selectors (without transmission bridge), then the **B1** contact in the final selector is essential to maintain the backward holding conditions. There are, moreover, a number of occasions when the final selector may be seized from special circuits or by testing equipment and in these cases also a guarding and holding earth may be essential. The same observations apply to the intermediate selectors. During the setting up of a call, it is usual to provide a temporary holding and guarding earth at each intermediate switching stage (contacts **B1** shown by

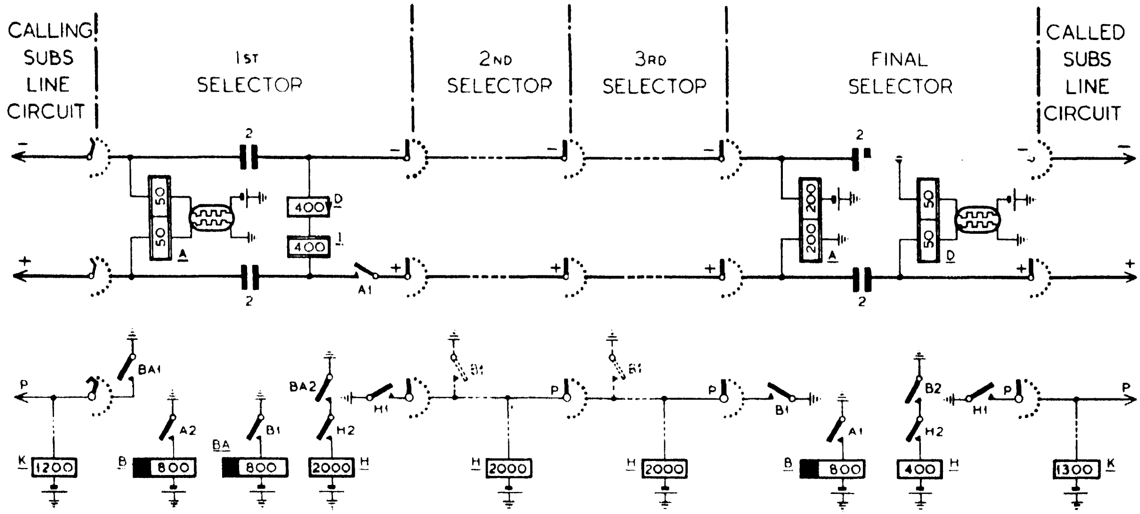


FIG. 289. A 5-DIGIT EXCHANGE WITH CIRCUITS ARRANGED FOR FORWARD HOLDING

broken lines in Fig. 289). This is the usual arrangement for a backward holding system, and, although the contacts may serve no useful purpose if the call is controlled on a forward holding basis, they may nevertheless be required under other circumstances.

To summarize, if a system of forward holding is employed, there is no necessity for holding earths to be applied by the intermediate or final selectors on local calls. In practice, however, the intermediate and final selectors may also be used for incoming junction calls and for various other purposes where backward holding is required and hence, as a matter of policy, all intermediate and final selectors are provided with facilities for maintaining the earth on the P-wire.

Before leaving Fig. 289, it is interesting to examine the circuit conditions on an outgoing junction call. Assume, for purposes of explanation, that a certain level of the 2nd selectors is connected to an outgoing junction route. In these circumstances the 1st and 2nd selectors are held forward

from the *H1* contact of the 1st selector and no outgoing junction relay group of any sort is required. At the incoming end of the junction circuit, backward holding conditions will apply and the circuit arrangements will be similar to those already considered in Fig. 288.

Release Circuit (Pre-2000 Type Selectors). The restoration to normal of a pre-2000 type selector is accomplished by the operation of the selector release or *Z* magnet. The operation of this magnet withdraws the detents from the vertical and rotary ratchets and thereby allows the selector to restore to normal (see Chapter III). Generally speaking, a selector may be released either

(*a*) before it has switched to a free outlet, or
(*b*) after switching to a free outlet.

It is therefore necessary to provide two alternative methods of energizing the release magnet. If a call is abandoned before switching takes place, then the release magnet can be energized by the restoration of a break contact of the holding relay (*B1*). Once the magnet is energized, then local contacts on the mechanism must be provided to disconnect the magnet on completion of the release operation. This disconnexion is readily obtained by the insertion of off-normal contacts (*N1*) in the release magnet circuit so that the circuit is completed by the release of relay *B*, and is ultimately disconnected by the breaking of the off-normal contacts when the switch reaches its normal position.

If the release of a selector takes place after switching has been effected, then the release magnet circuit must be placed under the control of a break contact of the switching relay (*H1*), the latter in turn being controlled by the earth on the *P*-wire. To meet both conditions, the release circuit of a pre-2000 type selector is as shown in Fig. 290. It is a simple series circuit containing break contacts of relays *H* and *B* (the switching and holding relays respectively), together with off-normal contacts to disconnect the magnet on completion of the release movement.

Release Circuit (2000 Type Selectors). It has been seen that the release of a 2000 type selector is effected by establishing the rotary drive circuit so that the wipers are stepped out of the bank beyond the 11th rotary position. The wiper carriage now restores under the action of the carriage restoring spring, and finally the wipers rotate to their normal position. The release circuit of a 2000 switch is therefore somewhat different from that of a mechanism of the pre-2000 type, but the principles are the same. In the first place, it is necessary to have in the release circuit a break contact of the holding relay (*B*) and a similar contact of the switching relay (*C*). Off-normal contacts must also be inserted to break the rotary magnet circuit when the wiper carriage restores to normal. In order to provide the rotary drive, the rotary magnet interrupter contacts (*R1*) must also be included in the release circuit.

A typical release circuit of a 2000 switch is shown in Fig. 291. If the call is released before switching takes place, the restoration of contact *B1* completes the rotary drive circuit, and when the shaft restores to normal this circuit is broken at contacts *N1*. Similarly, if release occurs after switching, the release of contact *C1* completes the rotary drive circuit until the circuit is disconnected by contacts *N1*.

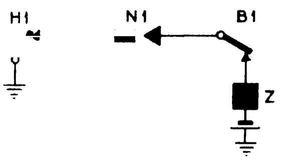


Fig. 290. Basic Release Circuit of a Pre-2000 Type Selector

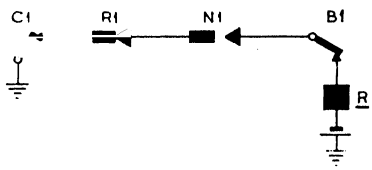


Fig. 291. Release Circuit of a 2000 Type Selector

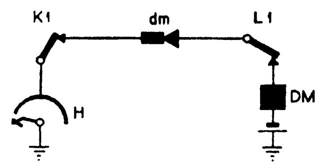


Fig. 292. Homing Circuit of Uniselector

Homing Circuit for Uniselectors. In most circumstances it is necessary that a uniselector should restore to its normal position after use. This restoration is commonly known as *homing*. If off-normal contacts were provided on a uniselector, it would be possible to adopt a homing circuit which is fundamentally similar to the release circuit of the 2000 type selector. Such contacts are not, however, provided on the standard uniselector, but the same facilities are given by the use of a *homing arc*. The homing arc is usually a solid sector which spans all but the normal contacts of the uniselector bank. The circuit is arranged so that a drive circuit for the uniselector mechanism is provided so long as the homing wiper is in contact with the homing arc, but when the wiper reaches the separate home contact this drive circuit is disconnected.

Fig. 292 shows the general design of a uniselector homing circuit. Whilst the uniselector is in use,

the homing wiper rests on the solid homing arc and thereby extends an earth to contact **K1**. As already explained in the above paragraphs, the homing or release circuit may be established either before or after switching. In the former case, the switching relay (*K*) is not operated but the release circuit is completed by the restoration of contact *L*1 of the line relay. If release is required after switching, then the removal of earth on the *P*-wire releases relay *K*, and the homing circuit is established by the restoration of *K*1. The release of *L*1 and *K*1 completes a circuit for the driving magnet via its own interrupter contacts (*dm*), and the wipers are therefore stepped round until they reach the normal

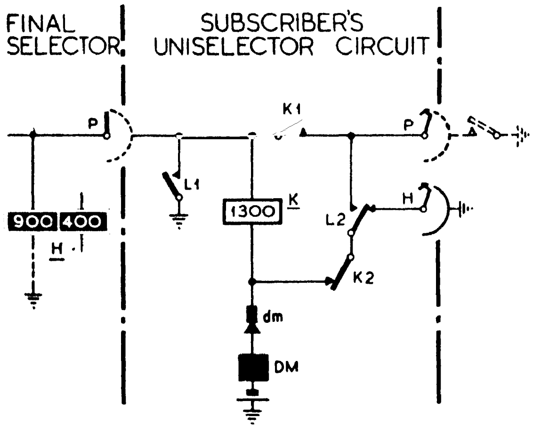


FIG. 293. PORTION OF SUBSCRIBER'S UNISELECTOR CIRCUIT SHOWING HOLDING AND RELEASE CONDITIONS

position when the earth is removed at the homing arc.

In some circumstances it is of advantage to arrange for two or more home positions of a uniselector. To avoid the manufacture of special banks with split homing arcs, it is usual in these circumstances to utilize an ordinary arc of the uniselector for homing purposes. By this means the bank contacts can be commoned together as required to provide any number of home positions to meet the circuit conditions. It is, of course, necessary under these conditions that the homing wiper shall be of the bridging type to avoid interruption of the drive circuit as the wiper passes from contact to contact.

Unguarded Periods During Release. It has been seen that in the circuits so far considered the switch mechanisms commence to release when the holding earth is removed from the *P*-wire. The earth on the *P*-wire, however, not only provides the holding condition prior to release, but also the guarding condition to prevent intrusion by other searching selectors. It is evident, then, that the withdrawal of the earth from the *P*-wire removes the guarding condition at the same time as it disconnects the selector holding circuits. Apart from any release lags of the holding relays, 2-motion selectors may require 500 msec or more to restore to normal. A similar time delay occurs on uniselector circuits before the mechanism reaches its home position.

The total release time is determined by a number of factors such as, for example, the lag of the holding relays, the position to which the mechanism is stepped, the adjustment of the mechanism and so on, but even under the most favourable conditions the release time may amount to several hundred milliseconds. During this time the selector or uniselector circuit tests free to any searching switch, and there is therefore a danger that a selector may be re-seized before it has completely restored to normal after the previous call. The probability of such re-seizure depends to a large extent upon the volume of traffic and upon the average time for which the selectors are held. There is, for example, a high danger of re-seizure during release when a selector forms part of common equipment which carries a high volume of traffic with a short holding time. The traffic to any individual subscriber's line, on the other hand, is, in comparison, small and there is therefore a much lower danger that this line might be seized whilst the uniselector is still homing.

The practical effect of re-seizure before a switch returns fully to normal depends upon the exact circuit arrangements. In some cases the seizure of a selector during release may cause the circuit to cut into another established connexion. In other circumstances the second call may be lost entirely or may be routed to a wrong number. There is also the possibility that interference will be caused to a number of established connexions during the passage of the wipers over engaged contacts.

It is of interest to examine the exact conditions which produce unguarded periods during the release of typical uniselectors, group selectors and final selectors.

Unguarded Periods with Subscriber's Uniselector Circuit. Fig. 293 shows the holding and release elements of a subscriber's uniselector circuit. The switching and homing principles already considered separately will be recognized. The *P*-wire of the final selector multiple giving access to the subscriber's line is engaged by the operation of contact **L1** as soon as the calling subscriber lifts his receiver. (There is, of course, a short period during the operate lag of the *L* relay when the circuit may be seized by a final selector, but this is not of great

consequence.) In due course relay K operates when a free outlet is found, and an earth is returned on the P-wire to maintain the holding and guarding condition in readiness for the release of L. During the conversational period, full guarding and holding is therefore provided.

If the call is abandoned before a free outlet is found (i.e. before relay K switches), the disconnexion of the subscriber's loop allows relay L to release, and after a short period of lag contact $L1$ removes the guarding earth from the P-wire. At the same instant, contact $L2$ completes the homing circuit for the uniselector. Earth is now extended from the homing arc via $L2$ and $K2$ to the battery side of the K relay. It is clear, therefore, that, although there is no full earth on the P-wire during homing, there is also no battery potential due to the presence of the earth from the homing arc. It has been seen in Chapter VII that battery testing is employed in all final selector circuits, and hence the absence of battery on the incoming P-wire of the subscriber's line circuit effectively prevents any final selector from switching to the line during the homing of the uniselector. The circuit may therefore be considered to be fully guarded under these particular conditions of release.

If the call is not abandoned before the uniselector has found a free outlet, an earth is returned on the P-wire to hold the K relay and to provide a guarding earth on the final selector multiple. At the end of the call, the removal of this earth allows relay K to release and, as before, $K4$ completes the homing circuit. There is, therefore, a short period equal to the release lag of relay K when there is no earth on the P-wire and when the battery from the driving magnet provides a switching condition for the final selector. After this time, the release of $K4$ applies earth to the battery side of the K relay and the circuit is guarded for the rest of the release time as described above. The unguarded period during the release of relay K is only in the order of 10 msec or so, and is of little consequence except, perhaps, on very busy P.B.X. lines when there is a small probability of switching during the unguarded period. If switching does occur before relay K releases, then a double connexion will result if the wipers are at that moment standing on an engaged outlet.

Apart from the above very short unguarded period, a subscriber's uniselector circuit on the lines of Fig. 293 may be considered to be reasonably well guarded during release. There is, however, a further factor to be considered. As will be seen later, registration of calls is often effected by the application of a positive potential to the P-wire at the final selector. This positive potential maintains the holding circuit of the various switching relays of the selector train, but unfortunately it provides the necessary battery potential required by the final selector switching circuit. There is, therefore, a danger with the uniselector circuit shown in Fig. 293 that a final selector may switch to an engaged subscriber's line circuit during the metering period. The positive potential is, in practice, applied for a period of some 300 msec, and there is, therefore, a fairly high probability of switching to an engaged line during metering in cases where the volume of traffic is high.

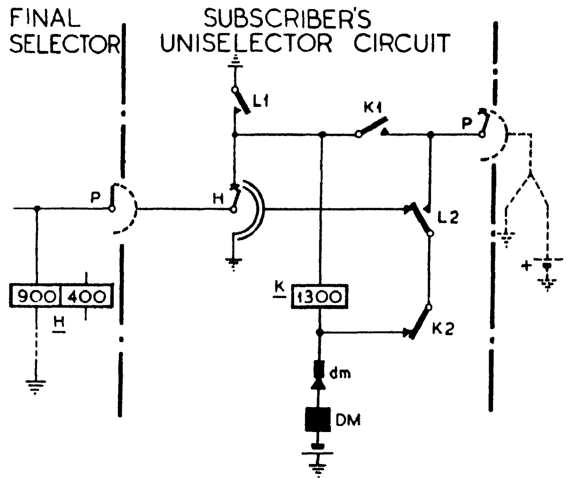


FIG. 294. USE OF DOUBLE HOMING ARC IN SUBSCRIBER'S UNISELECTOR CIRCUIT

Uniselector Circuit with Double Homing Arc. Subscribers' uniselector circuits of modern design make use of a double homing arc to obviate the unguarded period due to the lag of relay K on release and the very much greater unguarded period during metering. The circuit arrangements are as shown in Fig. 294. The P-wire from the final selector multiple is now connected to the homing wiper, whilst earth is connected to one sector of the solid homing arc. The circuit is so arranged that the final selector multiple is guarded by contact $L1$ as soon as possible after the lifting of the calling subscriber's receiver. As the switch drives from its normal position, the homing wiper passes on to the solid arc, and the guarding earth to the final selector multiple is now provided direct from the 2nd homing arc. When switching takes place (i.e. after the operation of K), the outlet seized is engaged first by contact $L1$ and later by the earth returned on the P-wire. This earth also holds the K relay.

The segregation of the incoming and outgoing sides of the *P*-wire prevents the positive battery from being applied to the final selector multiple during the metering condition, and therefore entirely eliminates the possibility of double connexions at this time. At the termination of the call, the removal of the earth from the *P*-wire allows relay *K* to release, and *K*2 in turn provides a driving circuit for the uniselector magnet from the earth at the homing arc (due to the bridging of the two segments by the wiper). By this arrangement, the earth is maintained on the final selector multiple until such time as the mechanism reaches the normal position, thereby eliminating the short unguarded period during the release lag of relay *K*.

Unguarded Periods of Group Selector Circuit. Fig. 295 shows the elements of the hold and release circuits of a pre-2000 type group selector

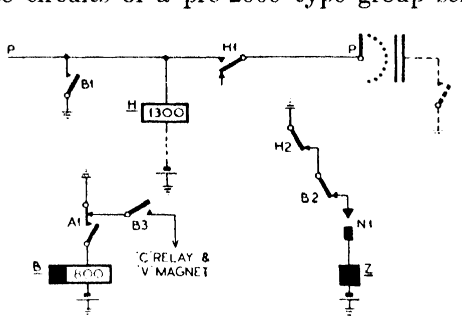


FIG. 295. PRE-2000 TYPE HOLDING CIRCUIT WITHOUT RELEASE GUARD FACILITIES

circuit without provision for guarding the release of the selector. If the call is abandoned prior to switching, it is clear that the release magnet circuit is completed at *B*2 coincident with the removal of the guarding earth on the *P*-wire at *B*1. The total unguarded period under these conditions is therefore the operate lag of the *Z* magnet plus the release time of the mechanism and the release lag of the magnet.

If the selector is released subsequent to switching, the removal of the earth from the *P*-wire at the final selector removes the guarding condition and disconnects the holding circuit for relay *H*. The unguarded period under these circumstances is therefore increased by the release lag of relay *H*.

With the 2000 type group selector, the unguarded period during release would be of a similar magnitude if special guard features were not provided. When a 2000 type selector is released prior to switching, the restoration of relay *B* disengages the *P*-wire whilst other contacts of the *B* relay complete the rotary drive circuit. The unguarded period would therefore be the time taken for the wipers to drive round to the 12th rotary position together with the vertical release time of the wiper carriage and the reverse rotary motion to the normal position. The worst condition occurs when the selector is to be released from the first contact of the 10th level. After switching, the selector is held by the earth on the *P*-wire which maintains the current through the hold coil of the *H* relay. The *H* relay in turn holds the *C* relay and the *C* contacts maintain the circuit through to the next stage. At the end of a call, the removal of the earth from the *P*-wire breaks the circuit for relay *H* which, in turn, allows *C* to release, and finally, contacts of the *C* relay complete the rotary drive circuit to start the release movement. The potentially unguarded period is therefore the summation of the release times of the *H* relay, the *C* relay, and the mechanical release time of the mechanism.

Guarded Release Circuit (Pre-2000 Type Selector). In the earlier designs of 2-motion selector circuit, no special provision was made to guard a selector during its release. It was therefore possible for a hunting circuit to seize a selector before the wipers had restored to their normal position. A mechanical latching device was introduced so that, once the detents were withdrawn from the teeth of the ratchets by the operation of the *Z* magnet, they were locked in that position until the vertical armature was operated on receipt of the first impulse of the succeeding call. This mechanical arrangement ensured that, if a circuit were seized during release, the consequent premature disconnexion of the *Z* magnet circuit would not interfere with the release action of the mechanism. Nevertheless this device does not provide full protection, since in some cases the first impulse of the next call may be received before the complete restoration of the mechanism from the previous call and, by releasing the detents, would possibly route the call to a wrong number.

In the later circuits of the pre-2000 type, arrangements are made to minimize the unguarded period during release. It is clear that, with the earth testing system commonly employed between the successive selectors of a switching train, there must inevitably be a short unguarded period to allow the switching relays to release. In Fig. 295, for example, the removal of the earth from the *P*-wire must be sufficiently long to allow the release of relay *H*, say 10 to 15 msec, but after this time it would be permissible to re-apply the earth to guard the switch against intrusion until it is fully restored.

Fig. 296 shows a typical pre-2000 type guarded release circuit. Contacts *Z*1 are associated with the release magnet armature and, during the release, an earth is applied to the *P*-wire from the time

that the Z magnet is operated until it is released when the switch restores to normal. Thus, the total unguard period is restricted to the operate time of the Z magnet if the circuit is released prior to switching, or to the release lag of the H relay plus the operate lag of the Z magnet if release should occur subsequent to switching. Hence, an unguarded period of up to 500 or 600 msec with the earlier circuits has been reduced to a much shorter period, in the order of 20 to 30 msec.

In addition to the guarding of the circuit during release, the **Z1** springs also disconnect the earth from the impulsing circuit during release. Thus, if a searching selector seizes the circuit during the short unguarded period prior to the operation of **Z1**, it is not possible for the second call to energize the vertical magnet (if, as is usual, the first release of $A1$ occurs after the operation of **Z1**). This minimizes interference with the release action which might otherwise result from the tripping of the release link by the vertical magnet. It should be noted that, if the selector is used in a train where the backward holding principle is employed, any circuit seizing the selector during the unguarded period would be released when the selector restores to normal. Thus, if switching takes place prior to the operation of $Z1$, a temporary holding earth is provided by the seizing selector until such time as contacts **Z1** operate. The circuits are then held backwards from the earth at **Z1** during the release period, but when the selector reaches its normal position, this holding earth is removed by the restoration of $Z1$ and there is a short break of the earth on the P-wire until such time as the B relay operates and re-applies the earth at **B1**. This short break of the holding earth on the P-wire during the operating lag of the B relay is usually sufficient to release any switching train established during the unguarded period. If a selector circuit is seized in the interval between the removal of the guarding earth on the P-wire and the time when the H relay releases, then the seizing circuit will maintain the H relay and may therefore cause the second call to be switched to the outlet used on the earlier call. The danger of this is in practice very small owing to the comparatively quick release time of the H relay.

If the selector forms part of a switching train where the transmission bridge is in the 1st selector, the final selector of the switching train is adequately guarded during its release by the longer holding time of the 1st selector which maintains an earth on the P-wire even after the loop to the final selector is disconnected. The intermediate group selectors are not, however, so guarded and, if they are seized during the unguarded period prior to the operation of the **Z1** contacts, the second call may be routed to a wrong number if any impulses are received during the release time of the selector. Such impulses are, of course, lost due to the removal of the earth from the $A1$ contacts by the **Z1** springs.

Although the guarded release circuit of the 2-motion selector is not 100 per cent perfect, it does nevertheless very materially reduce the time during which a selector can be seized. This degree of guarding is adequate in the group and final selectors of an ordinary switching train, but more elaborate measures are necessary in certain types of common equipment (e.g. in A-digit selectors) where the traffic is high and the holding time is short.

Guarded Release (2000 Type Circuits). In principle the guarding arrangements of 2000 type selector circuits are fundamentally similar to those

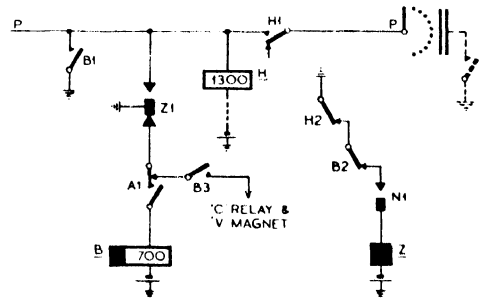


FIG. 296. PRE-2000 TYPE CIRCUIT WITH GUARDED RELEASE

of the earlier pre-2000 type circuits. But the absence of a separate release magnet and the use of the C relay for switching necessitates some slight re-arrangements. Fig. 297 shows a typical arrangement of a group selector circuit. If the circuit is released before the selector switches to the next stage, the circuit of relay A is broken at the originating telephone and $A1$ in turn releases B. The $B1$ contact now removes the guarding earth from the incoming P-wire, thereby allowing all the switching relays of preceding selectors to release. Other contacts of the B relay (not shown in Fig. 297) disconnect the C relay, and, after a short release lag, the $C1$ contact re-applies a guarding earth to the P-wire from the earth at the off-normal contacts **N1**. This earth is maintained until the switch restores to normal and contacts $N1$ change over. It is clear, then, that on release the earth is removed from the P-wire for a time equal to the release lag of relay C to allow all preceding switches to release. At the end of this time the earth is re-applied until the switch restores to normal.

If, now, release occurs after the group selector has switched, the removal of the earth from the *P*-wire allows relay *H* to release and *H*1 in turn

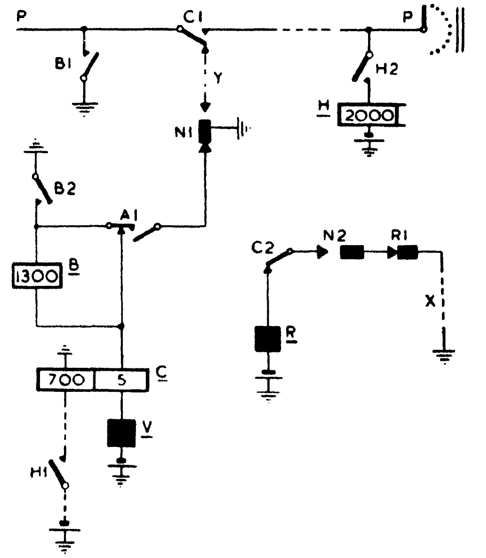


FIG. 297. PROVISION OF GUARDED RELEASE IN 2000 TYPE GROUP SELECTOR CIRCUIT

disconnects relay *C*. At the end of the release lag of *C*, *C*1 re-applies the earth backwards until such time as the *N*1 contacts open when the switch restores to normal. In these circumstances the *P*-wire is open for a period equal to the summation of the release lags of relays *H* and *C*.

Guarded Release of Final Selectors. The arrangements for guarding the release of final selectors are based on the same general principles as the group selector circuits illustrated in Figs. 296 and 297. The release conditions of a pre-2000 type final selector are, in fact, identical with the pre-switching release conditions of the group selector (Fig. 296). With 2000 type circuits, the *C* relay is energized during the conversation period, and at the end of the call the restoration of the *A* and *B* relays removes the guarding earth on the *P*-wire, and at the same time disconnects the circuit of relay *C*. After a short period of lag, the *C* relay restores to replace a guarding condition on the incoming *P*-wire until such time as the selector restores to normal (Fig. 298).

In some cases there are slugged relays in a final selector circuit which are held throughout the duration of a call, but are disconnected by the restoration of the *B* relay or on the return of the switch to normal at the end of the call. These relays may have an appreciable release lag, and the circuit arrangements may be such that several relays are released in sequence. There is therefore a danger, with some circuits, that certain of the controlling relays may not be fully restored to normal before the guarding condition is removed from the *P*-wire when the wiper carriage reaches its normal position (i.e. when the *N*1 contacts restore). In some circumstances this may be immaterial, but in other cases the re-seizure of a circuit with some of the relays operated may have very undesirable results. The guard feature can readily be extended to cover the release period of any slow relays by the provision of additional contacts, either in the release circuit of the selector or in the guarding circuit. If, for example, a slugged relay (e.g. relay *X* in Fig. 298) is controlled by relay *B*, it is possible to guard against re-seizure of the circuit with this relay operated, by including a break contact of the relay in the rotary magnet circuit of a 2000 type selector. By this means, release of the selector is held up until the relay fully restores—a guard being provided throughout the period by the ***N*1** contacts. This method cannot, of course, be employed where the holding circuit of a slow relay is controlled by off-normal contacts (e.g. relay *Y* in Fig. 298). In such circumstances, a make contact of the relay can be connected across the *N*1 contacts, so that the guarding earth is maintained on the *P*-wire until the *Y* relay is fully restored. The same scheme can, of course, be used if desired on group selector or other circuits.

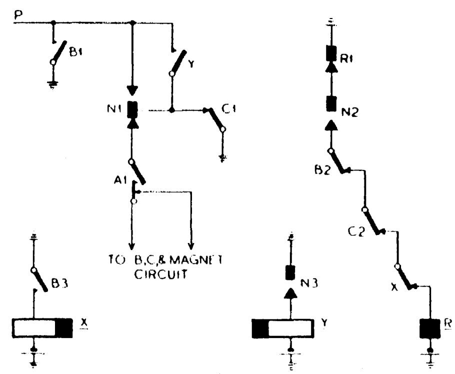


FIG. 298. GUARDED RELEASE CIRCUIT OF FINAL SELECTOR SHOWING METHOD OF COVERING RELEASE TIME OF SLUGGED RELAYS

In the circuit of Fig. 297 the contacts could be inserted as described above at points *X* and *Y*.

Fully Guarded Release. The release guarding schemes already considered provide a reasonable freedom from premature re-seizure when they are applied to the normal group and final selectors of a switching train. There is, nevertheless, an

unavoidable unguarded period prior to the re-application of the guarding earth when a selector can be seized before it has restored from a previous call. This period is so short that the probability of premature re-seizure is very small in circumstances where the number of switches hunting simultaneously is not great. In certain circumstances (especially with common apparatus, such as A-digit selectors and directors), the average holding time is very short and this, together with the large volume of traffic, very materially increases the probability of premature seizure. Moreover, in such circumstances it is usually of particular importance that such premature switching shall not take place.

It is impossible to eliminate completely the short unguarded period so long as earth testing is employed, but battery testing circuits can, on the other hand, be produced which provide complete immunity from re-seizure during release. As already explained in Chapter VII, it is possible with battery testing circuits to provide three distinctive conditions on the *P*-wire, viz.:

(*a*) An earth potential to indicate the engaged condition and to provide a holding circuit.

(*b*) A disconnexion to provide the engaged condition whilst the holding circuit is broken.

(*c*) A battery potential to indicate the free or disengaged condition.

It is clear, therefore, that complete guarding during release can be obtained with a battery testing circuit if the circuit is arranged so that the battery potential is only re-applied to the *P*-wire when the switch has completely restored to normal.

Fig. 299 shows a typical circuit which provides full guarding conditions during release. In this particular case, the switching relays are of the differential-hold type (as described in Chapter VII). When the selector is seized, the operation of the switching relay in the preceding stage applies earth (from **$H1$**) via the 20 Ω holding coil of the switching relay to the *P*-wire. This earth is of sufficiently low resistance to provide an adequate guard against seizure by other searching selectors. When the selector is stepped from normal, the initial holding circuit is broken at **$N1$** but is retained by the operation of the **$B1$** contact until such time as switching takes place when the function is taken over by the **$H2$** contact. If, therefore, the selector is released before switching takes place, the *P*-wire is disconnected at contact $B1$ to allow the preceding selectors to restore. The circuit is, however, fully guarded against re-seizure due to the absence of battery on the *P*-wire until the mechanism restores to normal and contacts $N1$ close. Similarly, if the circuit is released after the operation of relay H, the removal of the holding condition disconnects the circuit for the 20 Ω coil of H, which at $H2$ disconnects the *P*-wire backwards. Here, again, it is impossible for any other searching selector to re-seize the circuit until the battery on the *P*-wire is replaced by the restoration of $N1$ when the switch restores to normal. The combination of a fully guarded release circuit and a differential-hold type battery testing circuit is perhaps the most satisfactory arrangement to prevent irregular switching.

Guarding of Outgoing Junctions. It has already been seen that the *P*-wire is not usually extended to the junctions between two automatic exchanges.

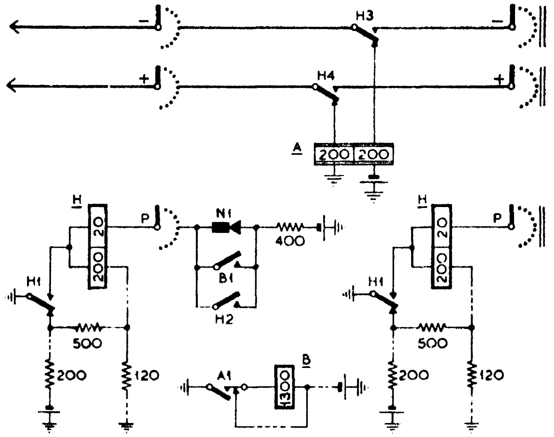


FIG. 299. DIFFERENTIAL TYPE TESTING CIRCUIT WITH FULLY GUARDED RELEASE

It follows that any guarding arrangements applied to the *P*-wire during release at the terminating exchange will be of no value in preventing the junction (and 1st selector) being re-seized when the guarding condition is removed from the outgoing end of the circuit. Usually the holding loop over the junction is disconnected at the same time as the circuit of the originating exchange holding relay is broken. Unless special arrangements are made, the outgoing junction tests free to any other searching selectors from the moment that the wipers leave the bank contacts. At this time the selectors at the distant exchange are also just commencing to release, and there is a further appreciable period before the incoming 1st selector has completely restored and is available for further use.

The lack of continuity of the *P*-wire between the two exchanges prevents the application of any guarding condition except on the speaking pair. As will be seen later, it is usual (for supervisory purposes) to arrange for the reversal of the current over the junction when the distant subscriber

answers. By so arranging the circuit that this reversal is not restored at the end of a call until the terminating selectors are fully released, it is possible (in certain circuits) to provide some measure of guarding. Even so, the guarding is incomplete in that it relies upon the call being answered before

(*b*) The release lag of relay *B* of the final selector at exchange *B*.

(*c*) The release lag of the switching relay (*H*) of the incoming 1st selector at exchange *B*.

(*d*) The actual release time of the incoming selector wiper carriage.

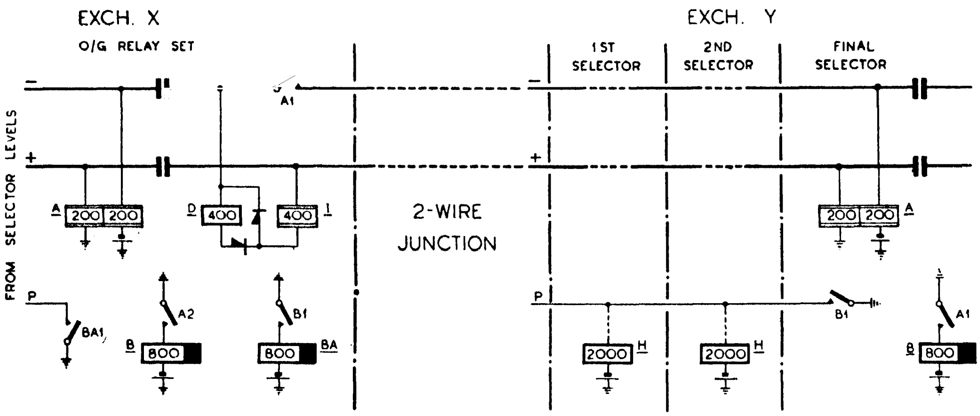


Fig. 300. Two-relay Guard on Outgoing Junctions

the necessary reversal is available to provide a guarding condition during release.

The most practicable and usual method of guarding an outgoing junction is to arrange the circuits so that the guarding earth on the *P*-wire at the originating exchange is maintained for a period sufficient to allow the switching train at the distant exchange to release. Fig. 300 illustrates the principle. At the end of a call, relay *A* at the originating exchange *X* releases and at *A*1 disconnects the loop forward over the junction to exchange *Y*. This in turn allows the bridging relay (*A*) at exchange *Y* to release. After a period of some 300 msec, the *B* relay of the final selector at the

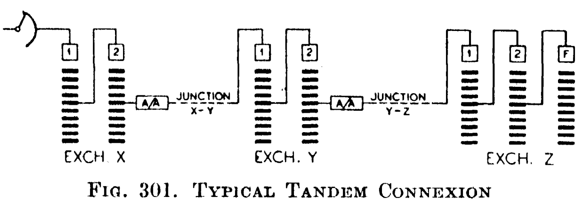


Fig. 301. Typical Tandem Connexion

terminating exchange removes the earth from the *P*-wire to allow the release of the preceding switches at the terminal exchange. The time between the release of relay *A* at the originating exchange and the complete restoration of the selectors at the terminating exchange is the summation of the following time elements:

(*a*) The release lag of relay *A* of the final selector at exchange *A*.

In order, therefore, to provide an adequate guard, it is necessary to prolong the guarding earth at the originating exchange for a minimum period which is not less than the above aggregate release time of the equipment at the terminating exchange. In practice, it is necessary to delay the removal of the guarding earth for a period of from 600 to 800 msec after the restoration of the *A* relay. It is impossible to obtain so long a release lag with the usual single guarding relay, and it is therefore usual to provide two guarding relays in tandem. When the calling subscriber replaces his receiver, the restoration of relay *A* at the outgoing exchange disconnects relay *B* at contact *A*2. After a delay period of some 300 msec, contact *B*1 disconnects the circuit for relay *BA* and, after a further release period of similar duration, contact *BA*1 restores to remove the guarding earth from the *P*-wire.

Tandem Calls. The principle of the 2-relay guard illustrated in Fig. 300 may lead to complications if it is applied to circuits which carry tandem traffic through one or more intermediate exchanges. Fig. 301 shows a simple tandem routing scheme in which a subscriber on exchange *X* can reach exchange *Y* via 2nd selectors at his local exchange. He can then dial through 1st and 2nd selectors at exchange *Y*, to reach a subscriber on exchange *Z*. For purposes of illustration it is assumed that the holding conditions at exchanges *X* and *Y* are provided by auto-relay sets connected to the outgoing junctions at these points.

At exchange Z the train of switches is held backwards from the final selector. When, at the end of a call, the calling subscriber (exchange X) replaces his receiver, the line relay in the local outgoing relay set releases immediately, and the clearing signal is passed forward over the junction X–Y to release the line relay in the outgoing relay set at exchange Y. Similarly, the release of this latter relay breaks the loop forward over junction Y–Z to release the A relay in the final selector at the distant exchange Z. The disconnexion of the holding loop throughout the chain of connexions takes place almost simultaneously on the replacement of the subscriber's receiver. (Actually there is a very slight delay due to the release lags of the line relays at exchanges X and Y, but this is not more than a few milliseconds.) The B relay at the terminal exchange (Z) now commences to release, and after a period of some 300 msec the restoration of the B relay removes the holding condition from the P-wire of the chain of selectors at exchange Z. If, say, it takes a period of 300 msec for the 1st selector at exchange Z to restore to normal, then it is clear that the outgoing relay set at exchange Y must guard the junction for a total period of $300 + 300 = 600$ msec from the opening of the loop. At the end of this period, the guarding relays at exchange Y restore to normal, and remove the holding condition from the 1st and 2nd selectors at the intermediate exchange. If the 1st selector at exchange Y also takes 300 msec to restore after the removal of the holding condition at the outgoing relay set, then provision must be made at exchange X to guard the outgoing junction to exchange Y for a total of $300 + 300 + 300 = 900$ msec. If a call were routed through two intermediate exchanges, then the guard at the outgoing exchange would have to be of the order of 1200 msec, and so on. Thus, the total time for which a junction guard is required depends upon the number of links in the connexion.

The difficulty can be overcome by the provision of a circuit on the lines of Fig. 302. Provision is now made for the release of the local train of selectors immediately on the restoration of the B relay, but a guard is provided on the outgoing junction circuit to cover the release time of the 1st selector at the distant end. Thus, a junction guard of some 300 or 400 msec will suffice under all conditions, irrespective of whether the call is routed through one or more exchanges.

The operation of the A relay from the subscriber's loop energizes relay B, and **$B1$** applies a holding and guarding earth backwards on the P-wire to hold all previous selectors in that exchange. At the same time **$B1$** operates relay BA. **$BA3$** provides a holding circuit for BA independent of contact $BB1$, whilst contact **$BA1$** closes the circuit for the BB relay. Thus, during the conversational time, relays B, BA, and BB are all operated and the guard is maintained on the P-wire by contact **$B1$**. At the end of the call, relay A releases, and at $A2$ disconnects the circuit of relay B. After a release lag,

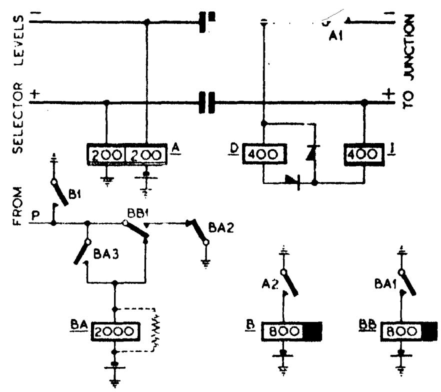


Fig. 302. Typical Circuit to Provide Local Release and Junction Guard

$B1$ removes the holding earth from the P-wire and at the same time disconnects the circuit of relay BA. The latter relay is arranged to have a short release lag (of, say, 20 msec), and after this time the restoration of contact $BA2$ re-applies the guarding earth to prevent re-seizure of the junction by a second caller. This guarding earth is maintained (at **$BB1$**) until such time as relay BB restores after a lag period of some 300 msec.

If the system utilizes forward holding from the 1st selector, as in Fig. 289, it is not usual, nor is it necessary, to provide relay sets directly connected to the outgoing junctions. In these circumstances the hold-release-guard scheme of Fig. 302 cannot be incorporated in the 1st selector circuit for obvious reasons. The facility can, however, be provided (if desired) by the fitting of a pair of junction guard relays to the P-wire at the outgoing junction point. These relays could conveniently be wired in exactly the same way as the BA and BB relays in Fig. 302.

EXERCISES VIII

1. What do you understand by the terms "backward holding" and "forward holding"? Describe, with the aid of simple diagrams, how holding and guarding conditions are maintained during the setting up of a call in a 4-digit exchange where the circuits are arranged for backward holding.

2. What factors determine the position of the transmission bridge in an automatic switching train? Draw a simple trunking diagram of a 3000-line automatic exchange with 40 outgoing junction routes all of which are trunked from 2nd selector levels. Show on the diagram where you would locate the transmission bridges.

3. Design, for a 2-motion selector, a circuit which will give the following facilities:

(*a*) Vertical stepping under the control of the calling subscriber's dial.

(*b*) Automatic drive over the selected level.

(*c*) A battery testing circuit which will switch to the first free outlet on the level.

(*d*) Local holding and guarding conditions during the progress of a call.

(*e*) Release of the mechanism at the end of the call.

4. Show how, in a subscriber's uniselector circuit, an outgoing call is guarded against intrusion during the establishment and release of the call. What is the purpose of the double homing arc often provided in such circuits?

5. Describe, with the aid of simple diagrams, how a 2-motion selector may be re-seized before it has completely restored from the previous call. What circuit arrangements can be made to minimize this danger?

6. An important piece of common apparatus is in constant use during the busy hour. The average holding time is 5 sec. Give a diagram of a suitable testing and guarding circuit, and explain why you have selected this circuit.

7. In a final selector circuit a certain relay is held throughout the conversation, but its circuit is broken by the opening of the off-normal springs when the selector restores to normal. The relay has a copper slug which produces a release lag of about 300 msec. It is very desirable that the selector should not be seized whilst this relay is still operated from the previous call. How would you meet this requirement?

8. In a group selector circuit of the 2000 type, the earth is removed from the *P*-wire for 25 msec before the release guard is applied. Describe what would happen if a group selector of the preceding stage should reach this outlet 20 msec after the removal of the earth from the *P*-wire. Illustrate your answer with suitable diagrams.

9. Describe two methods of preventing the seizure of an outgoing junction before the selectors at the distant exchange are released. Which method would you use if the outgoing junctions are used for tandem traffic through one or more intermediate exchanges?

10. Examine the possibilities of providing a signal (over the speaking pair) between two automatic exchanges to indicate that the selectors at the incoming end of the circuit are not fully released. Show how such a signal could be used at the outgoing exchange to guard against re-seizure of the junction until conditions are normal at the incoming exchange.

CHAPTER IX

SUPERVISORY AND METERING CIRCUITS

AUTOMATIC exchange circuits must provide for the transmission of suitable supervisory signals to any manual exchange through which a call may be routed. The supervisory signals are particularly important when an automatic subscriber is connected to a trunk or toll exchange where the signals are required for the control of the automatic call timing devices. In addition to the supervisory signals, automatic switching circuits must also provide for the automatic registration of all local and junction calls which are established by direct dialling from the subscriber.

The circuit principles used to give the above facilities are very closely allied, and are considered together in this chapter.

Supervisory Signals to Manual Operator on Calls from Automatic Subscribers. All automatic selector circuits are designed to work with loop calling and disconnexion clearing signals from the subscriber's telephone. In ordinary circumstances there is no reason to change these basic signalling conditions when a call is extended through automatic selectors to a manual switchboard. Fig. 303 shows the signalling elements on a call routed through a subscriber's uniselector circuit and a group selector at the automatic exchange to a manual board of the sleeve control type located in the same building.

The subscriber's calling loop is extended forward at each switching stage, and, when the manual board circuit is seized, relay L operates to this loop. **$L1$** operates the slugged relay (B), and **$B1$** in turn lights the calling lamp. When the operator inserts a plug into the line jack, relay S operates, and at **$S1$** extinguishes the calling signal. At the end of the call, the disconnexion of the loop at the subscriber's instrument allows $L1$ to restore which, by short-circuiting the 5000 Ω winding of relay S, allows the cord circuit supervisory lamp to glow. The subscriber can obtain the attention of the operator at any time during the progress of the call by flashing his cradle-switch, the alternate operation and release of $L1$ repeating the flashing signal to the cord circuit supervisory lamp.

The circuit is arranged to provide backward holding of all automatic selectors from the manual board circuit. The initial holding condition is provided by contact **$B2$** and, when the telephonist replies, this is supplemented by a secondary holding earth from **$S2$**. Thus, the switching train is held, and the connexion is guarded against intrusion until such time as the calling subscriber replaces his receiver or the operator withdraws the plug—whichever is the later. The slow-to-release relay (B) is inserted in this circuit to guard against premature release of a connexion should the subscriber continue dialling after switching to the manual board circuit. This relay has a release lag of the order of 300 msec, and provides a continuous earth on the P-wire even although relay L is pulsed at impulse frequency.

Fig. 303 shows a line relay with ballast resistor. This is a common arrangement on circuits used for the completion of trunk and toll calls where the maximum transmission efficiency is desirable. (The apparent reversal of the speaking pair in Fig. 303 is merely due to the standard convention in automatic exchange circuits of drawing the + line below the − line, whereas, in manual exchange circuits, the + line is connected to the tip of the jack.)

Although loop calling is the normal method of signalling from an automatic exchange to a manual board, various alternative forms of signalling are used in special circumstances. In certain cases, different calling conditions are required over the same circuit to discriminate between calls of various types. For example, a common group of circuits to the automanual switchboard may be used to carry calls, both from ordinary subscribers and from coin-box lines. Generally speaking, any of the following signals can be employed to indicate alternative conditions on the same circuit:

(*a*) Loop calling.
(*b*) Earthed loop calling.
(*c*) Battery on A, earth on B.
(*d*) Battery on B, earth on A.

The detailed circuit arrangements when two or more alternative calling signals may be required are usually fairly complex and are considered later in this volume (see Chapters on U.A.X.s).

Manual Hold. On purely automatic calls, the holding and release of the train of selectors is controlled by the calling subscriber. On calls from an automatic subscriber to a manual board, however, it is often desirable to provide facilities whereby the manual exchange operator can take over the control of the switching train from the calling subscriber. This facility is known as *manual*

hold (or sometimes as *operator hold*). If the manual board is in the same building as the automatic equipment, it is readily possible to extend the *P*-wire to the manual board relay set. In these circumstances manual hold can be provided by arranging for earth to be returned on the *P*-wire until such time as the plug is removed from the jack. Fig. 303 is a manual hold circuit of this type. It will be noted that the *K* and *H* relays of the subscriber's uniselector and group selector circuits are held by contact *S2* for so long as relay *S* is energized by the presence of a plug in the line jack.

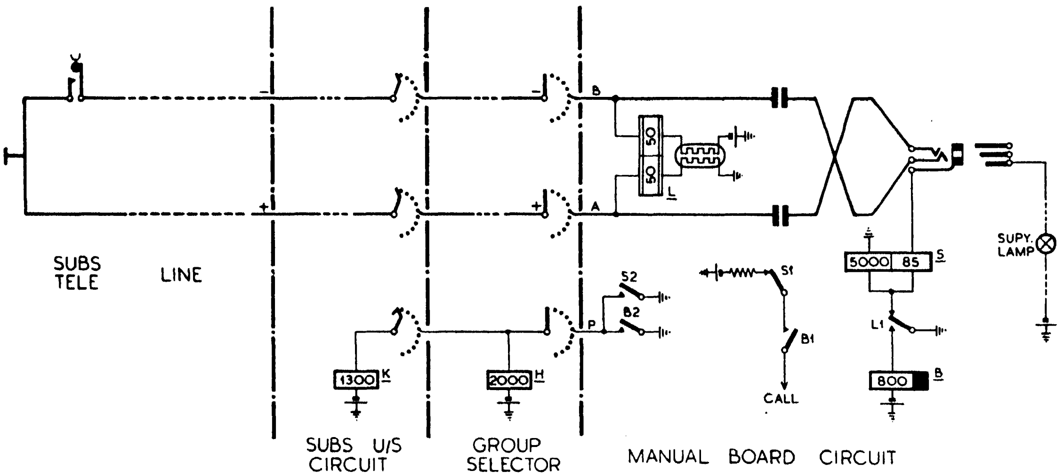


FIG. 303. LOOP CALLING CONDITIONS FROM AUTOMATIC SUBSCRIBER TO MANUAL SWITCHBOARD (AUTOMATIC SWITCHING TRAIN HELD BACKWARDS FROM MANUAL BOARD RELAY SET)

If the manual board is at some distance from the building which accommodates the automatic equipment, it is usually impracticable to extend the *P*-wire over the junction. The manual hold facility must then be provided by a suitable signal returned from the manual board over the speaking pair to the automatic exchange. The signal usually takes the form of a reversal of the line current when a plug is inserted in the jack. This signal is used at the automatic exchange to provide a hold condition on the local *P*-wire independent of that provided by the calling subscriber's loop. The circuit arrangements must be such that the manual hold signal does not interfere with the normal signals from the automatic exchange to the manual exchange. For instance, irrespective of the manual hold condition, the operator must receive a clearing signal

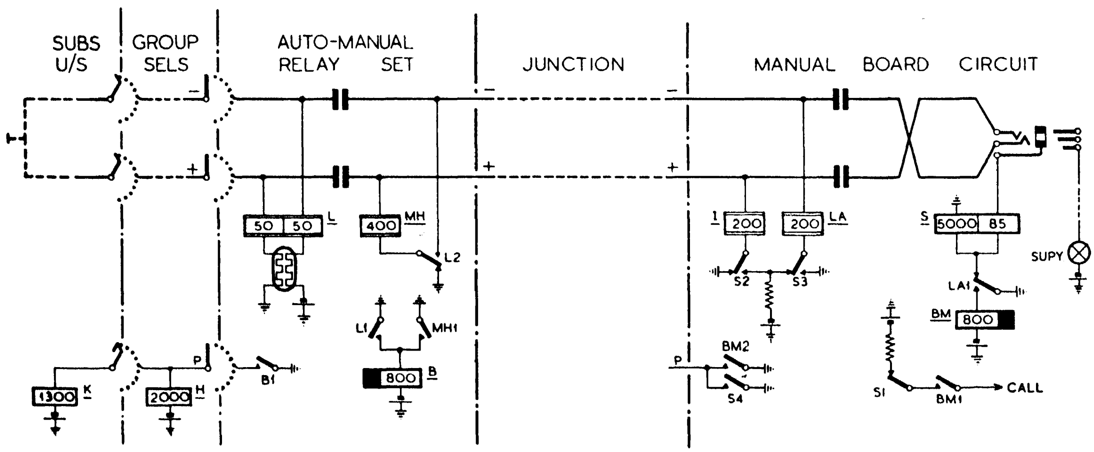


FIG. 304. SIGNALLING CONDITIONS FOR MANUAL HOLD (WITH REMOTE MANUAL BOARD)

from the calling subscriber when he replaces his receiver, and also any further calling or flashing signals from the subscriber.

Fig. 304 shows a typical arrangement where the train of automatic selectors is held from a relay set directly connected to the outgoing junction circuit. When the outgoing relay set is seized for a call, the subscriber's loop operates relay L, and **$L1$** in turn operates relay B to provide a holding and guarding earth backwards on the P-wire. Contact **$L2$** completes the calling loop forward to the manual exchange via relay MH which operates to the loop current. At the manual exchange, the extended calling loop operates A (or +) wire to the earth at $L2$. **$MH1$** holds relay B, and thereby prevents the release of the automatic selectors. This condition persists until the operator removes the plug from the jack, when the restoration of $S2$ removes the battery from the + line to release relay MH. $MH1$ now disconnects the circuit for relay B, and after a release lag period, the holding earth is removed from the P-wire at $B1$. It will be noted that the calling subscriber can regain the attention of the operator during manual hold conditions by lifting his receiver. The re-establishment of the loop re-operates relay LA, and **$LA1$** darkens the supervisory lamp of the cord circuit.

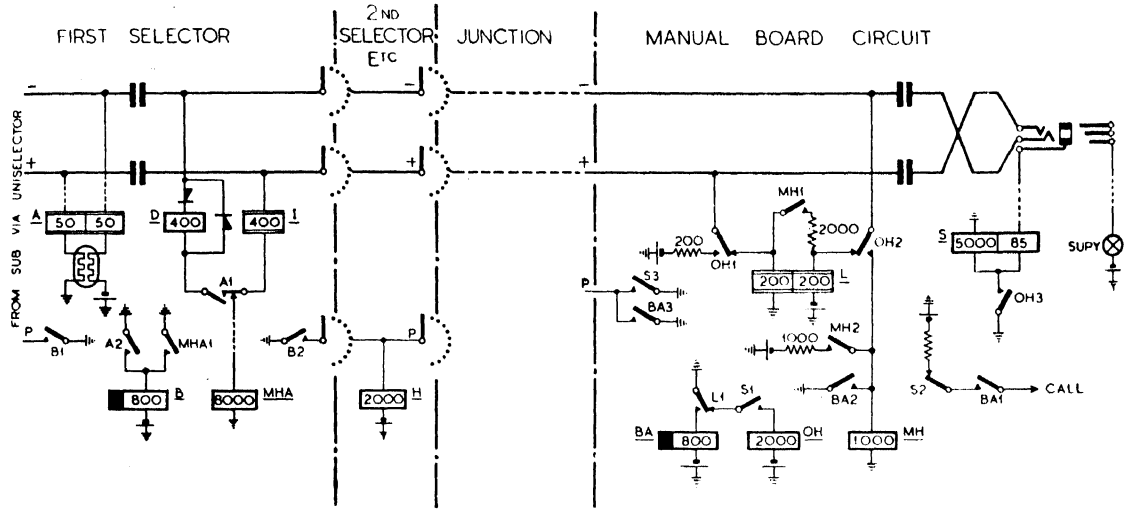


Fig. 305. Circuit Arrangements for Manual Hold when Switching Train is Held Forward from 1st Selector

relay LA, which at **$LA1$** operates the slow relay (BM) to light the calling lamp at **$BM1$**. When the operator answers, relay S operates over both coils in series to the battery on the sleeve of the answering plug. **$S1$** extinguishes the calling signal, whilst **$S2$** and **$S3$** reverse the direction of the current in the line to the automatic exchange. MH momentarily releases during the reversal, but re-operates when the current again builds up in the loop. The circuit is now set up for conversation and the train of automatic selectors is held by relay B under the joint control of relays L and MH.

When the calling subscriber replaces his receiver, the restoration of contact $L2$ breaks the calling loop forward to release LA at the manual exchange and to light the cord circuit supervisory lamp. Relay MH, however, remains held to the battery returned from the manual exchange over the

Manual Hold in Conjunction with Forward Holding at Automatic Exchange. It will be seen later that the reversal of line current is the standard method of transmitting the metering signal over a junction circuit. It follows that the manual hold circuit of Fig. 304 cannot be used on any circuit where it is necessary to return a metering signal to the automatic exchange. Moreover, the use of the same signal for manual hold or for metering causes some complications when the transmission bridge at the automatic exchange is located in the first selector. The first selectors are required for use on calls of all types, i.e. to local automatic subscribers, to other automatic exchanges, as well as to distant manual boards. The selector is not able to differentiate between a reversal, which in one case may mean manual hold, and in other cases may be a signal for metering. In such cases the somewhat more complex arrangements of

Fig. 305 must be adopted. The main difference between this and the previous circuit (Fig. 304) is that the battery is not returned on the + line for manual hold purposes until such time as the calling subscriber replaces his receiver. By this means it is possible to arrange the first selector circuit so that a battery returned over the + line is interpreted as:

(*a*) a metering signal if the calling subscriber is in circuit at that time, and

(*b*) a manual hold signal if the calling subscriber has at that time replaced his receiver.

When a calling subscriber dials the code appropriate to a manual exchange route, the loop formed by the *D* and *I* relays and contact **A1** is extended forward over the junction to operate the + line back over the − wire of the junction to operate relay *MH* at the manual exchange. ***MH*1** provides a local re-operate circuit for relay *L*, and ***L*1** disconnects *OH*. The restoration of *OH*1 and *OH*2 restores the *L* relay to the calling loop, whilst *OH*3 extinguishes the supervisory lamp. Contacts *MH*2 and *BA*2 are provided to prevent a relay race when *MH* re-operates under recall conditions. Without these contacts there is a danger of relay interaction should *MH*1 restore before the alternative holding circuit of relay *L* round the junction loop is firmly established. ***MH*2** causes relay *MH* to lock until such time as the *BA* relay is re-operated. ***BA*2** now short-circuits the *MH* relay to provide a suitable release lag.

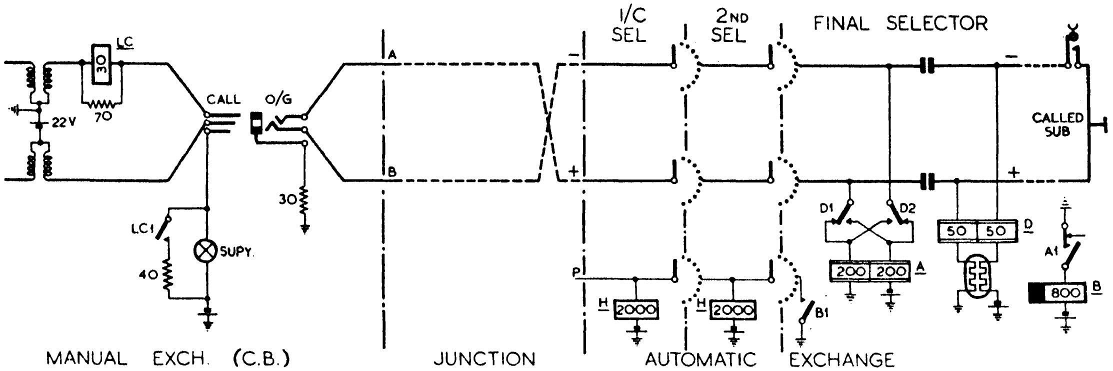


FIG. 306. METHOD OF RETURNING SUPERVISORY SIGNAL TO C.B. EXCHANGE OPERATOR

relay *L* at the distant manual exchange. ***L*1** operates *BA*, and ***BA*1** lights the calling lamp. When the call is answered, the operation of relay *S* extinguishes the lamp at *S*2, and the call can proceed. When the subscriber replaces his receiver, the restoration of contact *A*1 disconnects the calling loop and applies the high resistance *MHA* relay to the + line. At the manual exchange, the disconnexion of the loop releases relay *L*, and *L*1 completes a circuit for relay *OH*. ***OH*1** now returns a low resistance battery over the + wire, whilst ***OH*2** applies relay *MH* to the − line. ***OH*3** lights the cord circuit supervisory lamp. At the automatic exchange, receipt of battery on the + line operates *MHA*, and ***MHA*1** provides an alternative holding circuit for the *B* relay to hold the chain of selectors. (There is, of course, a short period between the release of *A*2 and the operation of ***MHA*1**, but this is adequately covered by the release lag of relay *B*.)

If the calling subscriber again lifts his receiver, the re-operation of **A1** extends the battery from

The high resistance of the *MHA* relay in the automatic exchange 1st selector prevents the holding of the final selector. *A* relay at the termination of an effective auto-to-auto call.

Supervisory Signals on Calls to Automatic Subscribers. On calls from a manual exchange to an automatic subscriber, facilities are required for the darkening of the cord circuit supervisory lamp when the called subscriber replies, and for the relighting of this lamp when he replaces his receiver at the end of the call. It is, in general, uneconomical to provide a separate automatic switching train for calls set up by manual exchange operators, and in practice the normal group and final selectors required for local traffic are also used for incoming calls from manual exchanges. This necessitates the provision on all selectors of a signalling circuit to return the supervisory condition when the called party replies. In this country the standard answering signal is a reversal of the current in the loop back from the automatic exchange to the manual switchboard. The reversal is controlled by the transmission bridge relay which

supplies current to the called party's transmitter. In the Post Office standard system the called party supervisory relay (normally designated *D*) is located in the final selector, but theoretically this relay can be located at any convenient point in the switching train.

Fig. 306 shows the fundamental circuit arrangements for providing the called subscriber supervisory signal. For purposes of illustration it is assumed that the call originates from a manual exchange of the C.B. type (see Vol. I). When the called party replies, relay *D* operates to the d.c. loop formed by the telephone instrument, and at **D1** and **D2** reverses the connexions of the *A* relay to the incoming + and — wires. The — battery now returned to the manual exchange on the + (or *A*) wire operates the supervisory relay (*LC*) in the cord circuit at the manual exchange. **LC1** darkens the calling cord supervisory lamp. It will be noted that relay *A* releases momentarily during the changeover time of the **D1** and **D2** contacts. The switching train is, however, maintained during the short break by the slow release feature of relay *B*. The selector train is held under pre-answer conditions by the current over the — line resulting from the difference in potential between the manual exchange and automatic exchange batteries. When the called subscriber answers, the selectors are held by the current in both windings of relay *A* from the battery and earth connexions in the manual exchange cord circuit.

Fig. 307 shows the comparable conditions at a manual switchboard of the sleeve control type. In this case the reversal of the line current causes relay *D* to operate, and **D1** in turn removes the

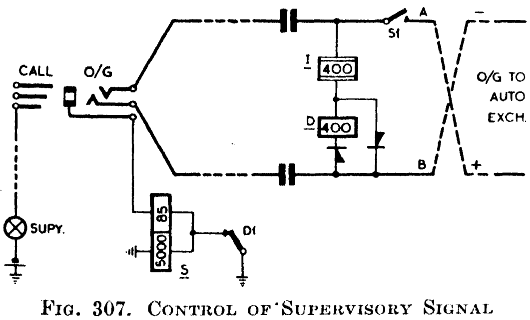


Fig. 307. Control of Supervisory Signal at Sleeve Control Exchange

short circuit from the 5000 Ω coil of *S* to darken the calling cord supervisory lamp.

Position of Reversing Contacts. It is interesting to examine the several alternative methods of effecting the current reversal required for the supervisory signal. In diagram *A* of Fig. 308, the reversing contacts are on the line side of the *A* relay and are of the make-before-break type. This was a common arrangement in a number of pre-2000 type circuits. With this circuit the current is not reversed in the coils of the *A* relay

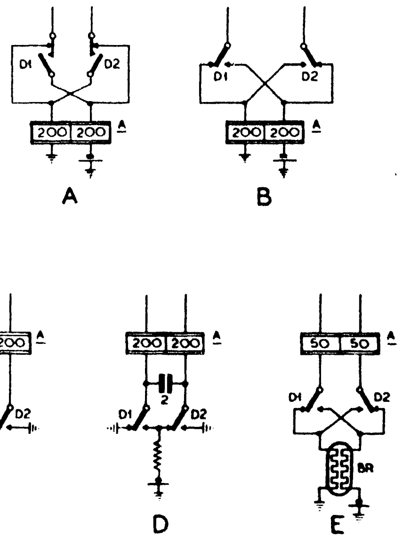


Fig. 308. Alternative Arrangements of Line Current Reversing Contacts

by the operation of the **D1** and **D2** contacts, but in most cases there is a momentary interruption of current through the windings due to the reversal of the charge on the line capacitance, and in some circumstances due to the reversal of flux in relays at the distant termination. By the use of make-before-break type contact units, it was hoped that the click resulting from the reversal would be minimized—due to the prevention of the momentary disconnexion of the circuit as the contacts change over.

Diagram *B* shows a similar circuit but utilizing contacts of the break-before-make type. In general it has been found that this type of contact does, in practice, produce less click than contacts of the make-before-break type. Diagram *C* shows the changeover contacts on the battery and earth side of the *A* relay. The operation of the contacts now reverses the current (and flux) in the *A* relay, so that there is a definite release of this relay during the changeover time. On the other hand, the presence of the relay inductance between the changeover contacts and the line has been found to reduce the volume of click. In the past, capacitors were sometimes fitted as shown in diagram *D*. The object of this capacitor was to produce a more gradual change of potential on the

A relay coils and so to minimize the intensity of the click on reversal. Diagram *E* is similar to diagram *C*, except that a ballast resistor is used in conjunction with a 50 + 50 Ω *A* relay.

Modern practice favours the arrangements shown in diagrams *C* and *E*. Where the ballast resistor type of bridge is used, then there is a saving in the protective resistor required with circuit *C*. This protective resistor must be of such a value that there is no risk of fire should the *D*

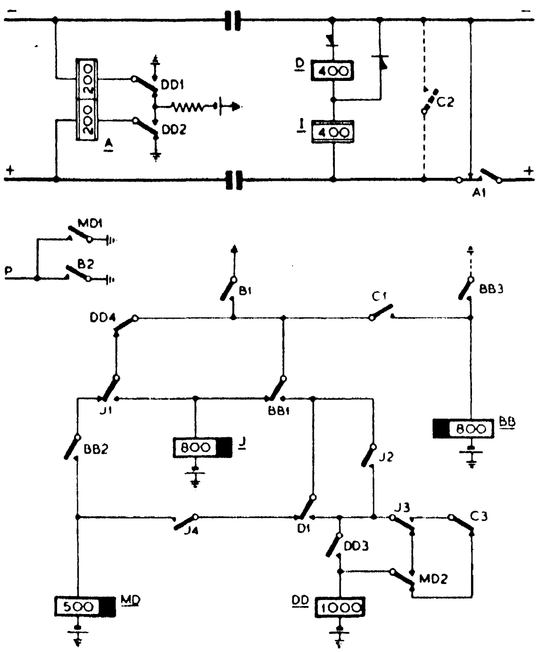


FIG. 309. METHOD OF REPEATING LINE CURRENT REVERSAL SIGNALS AT IMPULSE REPETITION POINTS

contacts become bunched due to maladjustment or to any other cause. Usually a resistor of 100 Ω is specified.

Although the main purpose of the break-before-make type of changeover contact is to reduce the volume of click (the click produced from such contacts is usually about half that obtained when make-before-break type contact units are used), it should be noted that the avoidance of contact bunching during the changeover period prevents a momentary flick of relay *A* when the *D* contacts restore at the end of the call. In some circuits this may be very undesirable, and the effect must be masked.

Repetition of Reversal at Bridges. It is necessary to make provision at all impulse repetition bridges for receiving and re-transmitting the supervisory signal when the called party replies. Fundamentally this repetition circuit could consist of a polarized relay in the forward loop circuit which would operate to the line reversal, and a pair of changeover contacts in the *A* relay circuit on the calling side of the bridge (Fig. 309). In practice, this simple scheme is unsatisfactory owing to the tendency for flick operation of the polarized relay from surges produced during impulsing and the subsequent switching operations. In the first place, the line reversal produced for supervisory purposes may, in some cases, control the metering of the call. It is most important that false metering should be avoided. Apart from this, however, any interruption of the *A* relay circuit (due to flick operation of the changeover contacts) during impulsing may have serious results and, even if there is no interference with the impulsing and switching operations, there is always a liability of severe clicks.

It is the usual practice to control the reversal of the current in the backward loop indirectly through a circuit which is designed specially to suppress flick operations of the supervisory relay and to introduce a time delay to prevent the reversal being applied during any short irregular operation of the *D* relay.

Fig. 309 shows a typical arrangement. Relay *B* operates as usual when the circuit is seized, and ***B*1** energizes relay *J*. ***J*1** provides an alternative holding circuit for *J* in readiness for the operation of *BB*1. At the first impulse, relay *C* operates and ***C*1** completes a circuit for the *BB* relay which holds via one of its own contacts. ***BB*1** now operates relay *MD* via *D*1 and ***J*4** (the *J* relay holds via ***J*1** and *DD*4 when ***BB*1** operates). The circuit remains in this condition until the called party replies, when relay *D* operates to the reversal in the forward loop applied at the distant exchange. ***D*1** disconnects the circuit for *MD*. After a release lag of some 200–300 msec, *MD*2 restores, and extends the earth from ***B*1** via ***BB*1**, ***D*1**, ***J*3**, and *C*3 to the *DD* relay. ***DD*1** and ***DD*2** now reverse the current in the backward loop. It will be noted that there is a delay in the retransmission of the supervisory signal which is equal to the release lag of relay *MD* plus the operate lag of relay *DD*.

This comparatively long delay feature ensures that the initial supervisory condition (which, it must be remembered, may also be used for metering) cannot be returned unless relay *D* is operated for a period of some 300 msec. Facilities must be provided for the called subscriber to flash the manual exchange operator if, at any time during the progress of the call, he should wish to

obtain her attention. A long delay in the transmission of the supervisory signal cannot be tolerated under flashing conditions. The circuit conditions are therefore changed after the first transmission of the supervisory signal by the release of relay *J* at contact ***DD*4**. Contact *J*3 now makes the operate circuit of relay *DD* dependent upon the make side of ***MD*2**. Hence, when the called subscriber replaces his receiver for flashing, the restoration of *D*1 releases *DD*, and *DD*4 re-energizes *MD*. ***MD*2** now prepares the circuit of relay *DD* in readiness for the next operation of ***D*1** when the called subscriber lifts his receiver. With this arrangement there must be an interval between successive operations of the ***DD*1** and ***DD*2** contacts at least equal to the operate lag of relay *MD*.

The circuit may be released at any instant and, to prevent the re-seizure of the circuit with some of the slow relays still energized, contact ***MD*1** is provided to maintain a guard on the incoming *P*-wire until such time as the *MD* relay has restored to normal.

Busy Flash (Pre-2000 Type Circuits). Operating procedure is simplified if a visual signal can be given to a telephonist to indicate that busy conditions have been encountered. The normal visual signal to indicate busy conditions is the regular flashing of the supervisory lamp at the speed of busy tone (i.e. 0·75 sec on, 0·75 sec off). The facility is known as *busy flash*, and on calls to an automatic subscriber it requires the provision of an additional signal over the speaking pair. On calls from a C.B. exchange to an automatic subscriber, the cord circuit supervisory relay is operated by a battery on the + or *A*-wire. In the pre-answer condition the + wire is connected to earth at the automatic exchange so that the supervisory relay is normal and the cord circuit lamp glows. Busy flash can be obtained by replacing the earth on the *A*-wire by a battery potential for 0·75 sec every 1·5 sec. This battery will then operate the supervisory relay to darken the lamp at regular intervals.

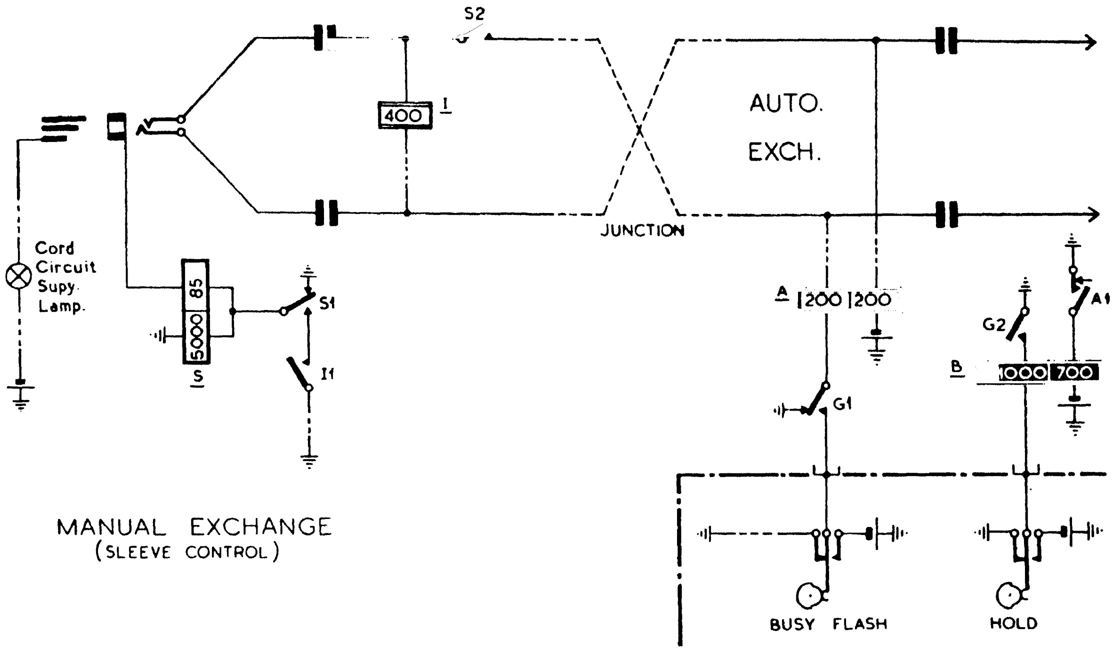


Fig. 310. Principle of Busy Flash Circuits—Sleeve Control Switchboard Working into Pre-2000 Type Exchange

If the call originates from a manual board of the sleeve control type, it is necessary to provide a relay across the loop which will release when the loop current ceases due to the application of the busy flash battery on the + line. Fig. 310 shows a typical circuit element of a call from a sleeve control manual board to an automatic exchange of the pre-2000 type. If busy conditions are encountered, contact ***G*1** operates to remove the normal earth from one coil of the *A* relay and to extend this coil to slow speed interrupter contacts on the ringing machine. These contacts are

arranged to apply earth for 0·75 sec, followed by battery for the next 0·75 sec, and so on. During the application of earth, the *I* relay in the outgoing manual exchange is operated, and at ***I1*** short-circuits the 5000 Ω winding of relay *S* to cause the cord circuit supervisory lamp to glow. During the ensuing flash period, the earth is replaced by battery, and the *I* relay releases due to the cessation of the loop current. The restoration of *I1* increases the resistance of the sleeve circuit and dims the supervisory lamp.

The *A* relay of the automatic selector is normally held by the loop current. When this current is interrupted due to the application of busy flash battery, the *A* relay releases. This would cause a

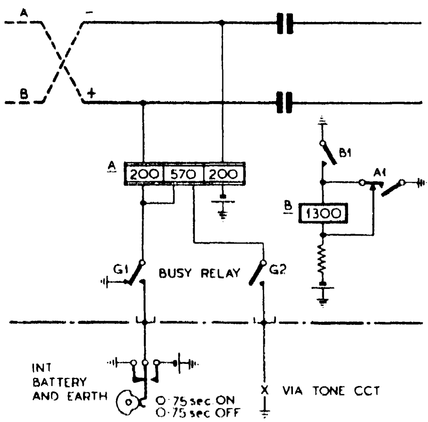


FIG. 311. BUSY FLASH CIRCUIT ON 2000 TYPE SELECTORS

breakdown of the connexion if arrangements were not made to hold the *B* relay during the 0·75 sec release periods of relay *A*. In pre-2000 type circuits the *B* relay has a second coil (Fig. 310), and, when busy flash conditions are encountered, contact ***G2*** connects this second coil to a further slow speed interrupter contact of the ringing machine known as the *busy hold supply*. The busy hold contacts are synchronized with the busy flash contacts, so that current flows in the hold winding of the *B* relay whenever busy flash battery is applied to the *A* relay. During busy conditions, therefore, the *B* relay is alternately held by the ***A1*** contact and by the busy hold battery during each successive 0·75 sec period.

Busy Flash (2000 Type Circuits). In circuits of the 2000 type, arrangements are made to hold the *A* relay rather than the *B* relay during busy flash periods. Fig. 311 shows the circuit elements. As before, contacts ***G1*** and ***G2*** are operated (as will be seen later) when busy conditions are encountered. Contact ***G1*** connects interrupted battery and earth (0·75 sec on, 0·75 sec off) to one side of the 570 Ω coil of the *A* relay and also to the + line. At the same time, contact ***G2*** applies earth to the second terminal of the 570 Ω winding. The windings of the *A* relay are connected so that, during the flash period (when there is no holding current in the 200 Ω windings), the relay is held by current in the 570 Ω winding. By the adoption of this arrangement, it is unnecessary to provide a busy hold winding on the selector *B* relay, and the whole of the winding space of the latter is available to meet impulsing requirements (see Chapter V).

The interrupter springs of the busy flash battery and earth supply are necessarily of the ordinary changeover type, i.e. the moving spring leaves the back or earthed contact before it makes on the front or battery connected contact. The line current is therefore interrupted at the moment when the interrupter springs break, but the hold circuit is not established until a short time later when the moving spring makes contact with the battery connected spring. During this transit period, the *A* relay is held from the earth via ***G2***, the 570 Ω coil, the 200 Ω coil, the + line, the distant exchange loop, the — line, and the remaining 200 Ω coil of relay *A*, to battery.

Repetition of Busy Flash. The repetition of the busy flash signal across any impulsing or transmission bridge presents a fairly complex problem. The only method of detecting the flash signal on a loop calling circuit is the provision of a relay bridged across the speaking pair which will release when the normal earth on the + line is replaced by the busy flash battery. This relay (usually designated *I*) must work in conjunction with the supervisory relay (*D*), and both these relays must be excluded from the signalling circuit during impulse repetition. We have seen in Chapter VI how the *D* and *I* relays are excluded from the loop during impulsing by the closure of contacts under the control of the *C* relay.

At any impulse repetition point, the *I* relay is first operated when the initial loop is passed forward to seize the distant exchange selector. The relay is released during each succeeding impulse train, and, if the call is effective, the *I* relay must also release momentarily due to the reversal of line current when the supervisory signal is returned. Hence, contacts of the *I* relay cannot be used directly to return busy flash battery over the backward loop. Provision must be made for preventing the return of busy flash conditions when the *I* relay releases due to any of the above conditions, or due to current surges during impulsing or switching.

Fig. 312 shows a practical arrangement. The circuit is designed so that flash is not repeated until the *second* application of full length flash conditions from the distant exchange. On seizure, relay *A* operates to the calling loop, and relay *I* operates to the forward loop. During the first impulse train, relay *C* is operated to cut out the *D* and *I* loop from the impulsing circuit and, at the same time, to operate, at **C1**, relay *BB*. **BB1** now completes a circuit for relay *MD*, which locks independent of **BB1** at **MD1**. When *I* re-operates at the completion of the train, the earth from **A2** is extended via **I2** and **BB2** to hold the *BB* relay. *BB* is held for each succeeding impulse train alternately by the **C1** contact and the **I2** contact.

If, at the conclusion of impulsing, busy conditions are encountered, relay *I* again releases. If the release period is greater than the release lag of relay *BB* (i.e. some 300 msec), this relay restores and at *BB*2 prepares the circuit for the *BR* relay. On the next re-operation of relay *I* (i.e. at the end of the flash period), a circuit is completed for relay *BR* via **MD2**. **BR1** changes over to prepare a circuit for the operation of relay *DD* and, at the same time, holds relay *MD* over its second coil. **BR2** does not function at this stage. At the commencement of the next flash period, *I* again releases, and at **I1** completes a circuit for relay *DD*. Contact **DD2** transmits flash battery on the + wire towards the calling exchange. **DD3** provides an alternative holding circuit for *BR*. At the termination of the flash period, *I* re-operates to release *DD*, and *DD*2 in turn replaces the earth on the + line. This process continues for so long as the call is held. It will be noted that relay *BR* is held during each flash period by contact **DD3** and, during the interval between flash periods, by contact **I2**. The *MD*, *BB*, and *DD* relays are also used in connexion with the return of supervisory conditions (i.e. under the control of relay *D*) as shown in Fig. 309.

It will be clear that the circuit arrangements shown in Fig. 312 make the *I* relay completely ineffective before the first impulse train and during each succeeding impulse train. The release of *I* can only be effective between impulse trains and after the transmission of all the impulse trains if:

(*a*) The first release of *I* is greater than the release lag of relay *BB*.

(*b*) There is a subsequent make period at least equal to the pulse operate time of relay *BR*.

(*c*) There is a second release period equal to the pulse operate time of relay *DD*.

We have seen (Figs. 310 and 311) that, during the transmission of busy flash, it is necessary to provide a local holding circuit for the selector train (either by holding the *A* relay itself or by energizing a second hold coil of relay *B*). If a call is abandoned during the busy flash period, then the automatic switching train is held by the busy flash feature until the end of the flash period. It is necessary to guard against the re-seizure of an outgoing junction whilst the selectors at the distant exchange are still held under busy flash conditions. This guard is provided in Fig. 312 by contact **MD3**, which is placed in parallel with the

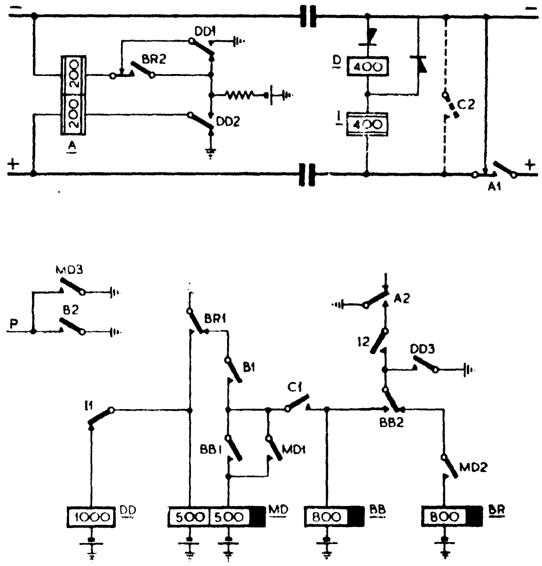


FIG. 312. REPETITION OF BUSY FLASH AT BRIDGES

usual *B* contact on the *P*-wire. Under flash conditions relay *MD* is held by relay *BR*, and the latter is held during the period of flash by contact **DD3**. If, therefore, a call is abandoned during a period of flash, *BR* is held until the end of that period, and the circuit of *MD* is broken after the release lag of *BR*. *MD*3 removes the guarding condition after the further release lag of relay *MD*. There is therefore a two-relay guard (*BR* and *MD*) from the end of the flash period to cover the release time of the distant selectors.

Metering. In a manual exchange system, effective calls are debited against the calling subscriber by the depression of the meter key at the end of the call, i.e. immediately before the telephonist breaks down the connexion. It would be theoretically possible to follow this principle in automatic switching circuits by arranging that the clearing signal from the calling subscriber initiated the metering condition (on effective calls) just

prior to the release of the chain of selectors. This method would, however, increase the holding time of the selectors, would complicate the holding and guarding circuits, and would prevent the subscriber from obtaining a second call immediately after the release of the first call. It is the

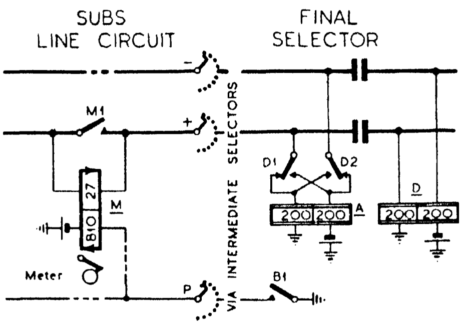


Fig. 313. Use of Polarized Meter in Subscriber's Line Circuit

standard practice in the British automatic system to meter the call when the called party replies, i.e. at the commencement of the conversational period.

The meters (or subscribers' registers) are of the electromagnetically operated, ratchet and pawl type, and are designed to debit one "unit" for each operation of the electromagnet. In modern exchanges the subscribers' meters are of the No. 100 type, which have been fully described in Vol. I. It is of the utmost importance that the metering circuits of an automatic exchange should have a low fault liability, and, in particular, the design must guard against irregular operation of the meter due to circuit faults or mis-operation by subscribers.

The tariff system of the B.P.O. is designed for the debiting of one unit for each effective call up to 5 miles radial distance from the originating exchange. Where technical considerations permit, direct dialling by the subscriber to exchanges up to 15 miles radial distance is permitted, and the charge for such calls may be two, three, or four units, depending upon the radial distance between the terminating exchanges. All of these calls are "untimed," i.e. the charge is independent of the duration of the conversation. Calls to exchanges beyond 15 miles are normally handled at the automanual switchboard, and are debited against the calling subscriber by the preparation of call tickets—the charge being determined jointly by the distance and by the duration of the call.

Reverse Battery Metering. We have seen that a supervisory signal to a manual exchange operator is obtained by reversing the line current in a backward direction when the called subscriber replies. In most of the earlier systems of automatic telephony, this reversal of line current was also utilized to operate the calling subscriber's meter on purely auto-to-auto calls. Fig. 313 shows a very early metering circuit in which a polarized meter is connected direct in the line circuit. The meter (*M*) has two windings, one of which is a polarizing winding, and the other the line winding. During the establishment of a call, the currents in these two windings are mutually opposing, and the meter does not operate, but, when the called party answers, the reversal of line current towards the calling party causes the meter to operate. Once operated, the meter holds on its polarizing winding and the line winding is short-circuited. This simple circuit was soon abandoned due to the difficulty of designing a meter which would be easy to adjust to the close limits required and which would be reasonably cheap to manufacture.

Fig. 314 shows a development of the same principle in which a polarized relay is provided in the 1st selector circuit. This relay receives the metering signal when the line current is reversed and completes a local circuit for the operation of a single coil meter in the subscriber's line circuit over a separate meter wire. There is a number

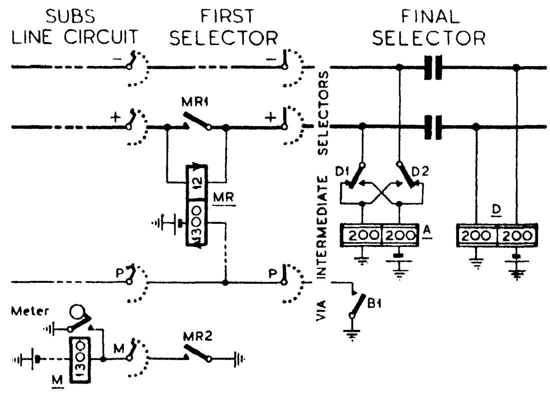


Fig. 314. Polarized Metering Relay in 1st Selector with Metering over Fourth Wire to Subscriber's Line Circuit

of variations of this principle, but all circuits of this type suffer from the disadvantage that an impedance is included in the line during dialling. The method is, moreover, not suitable for multiple operation of the meter (*multi-metering*) and requires that a reversal be given on all types of call.

Control of metering from the reversal of line current is still retained for the transmission of a

metering signal between two exchanges where the absence of a third conductor on the junction makes it impossible to convey the signal over the P-wire. In some systems (e.g. the director system), a very high percentage of the originated calls is to other exchanges. In such circumstances it is usual to provide a polarized relay in the 1st selector circuit to receive the line reversal when the called party replies, and it is convenient also to use this polarized relay to receive a line reversal from the final selector to control metering on local calls.

In all modern circuits it is usual to locate the polarized relay at an impulse repetition point so that the relay can be excluded from the impulsing path and can be placed so that it causes the minimum interference with transmission. A typical arrangement is shown in Fig. 315. A polarized relay of the shunt-field type is shown in this instance, although this may be replaced by an ordinary type of relay in conjunction with metal rectifiers (see Fig. 305). The 2000 Ω polarizing coil of relay D is operated when the circuit is seized, but the relay does not operate until the line current is reversed when the called party replies. Contact **$D2$** now disconnects the holding circuit of MD and, after a delay period of some 200–300 msec, $MD1$ applies earth to the meter wire (provided that **$D1$** is still operated). This delay feature prevents false operation of the subscriber's meter which might otherwise occur due to flick operation of the D relay. Once the meter is operated, it locks to its own contacts until the termination of the call thereby providing a safeguard against over-registration should the D relay release momentarily during the progress of the call.

Fourth-wire Metering. The circuit elements given in Figs. 314 and 315 necessitate the provision of an additional conductor between the subscriber's line circuit and the point at which the metering condition is applied. Any system of this type is known as a *fourth-wire metering* scheme. The introduction of an additional metering wire involves the provision of additional wipers at each switching stage through which the metering signal must be passed. This adds materially to the cost of the system and, in general, fourth-wire metering can be justified only where the signal is applied at the 1st selector stage. This requires an additional wiper and bank on the subscriber's uniselector or on the linefinder, but the extra cost is largely offset by the simplification of the metering circuit by the use of the fourth wire.

In some circuits an earth potential on the meter wire constitutes the metering condition, but in other circuits a battery potential on the meter wire is employed. The former scheme is often known as *fourth-wire earth metering*, whilst the latter is referred to as *fourth-wire battery metering*. Generally speaking, battery metering is to be preferred owing to the lower probability of a fortuitous application of the metering signal to the M-wire.

Booster Metering. We have seen that, in an automatic scheme where a high percentage of the traffic is to local subscribers, it is usual to locate the transmission bridge in the final selector stage. In these circumstances it is most undesirable, both on transmission and on impulsing grounds, to provide a polarized relay in the 1st selector which could respond to a reversed line current condition returned from the final selector. Similarly, it is

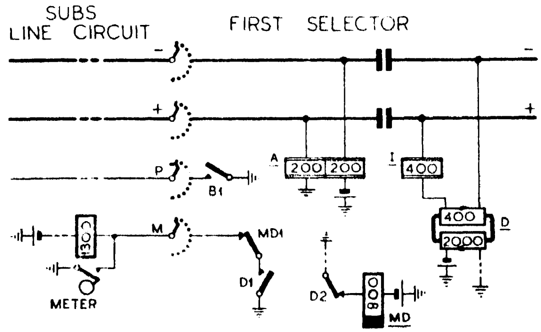


FIG. 315. FOURTH-WIRE METERING WITH TRANSMISSION BRIDGE IN 1ST SELECTOR

economically wasteful to extend the meter wire from the subscriber's line circuit through several stages of group selection to the final selector.

The alternative is to utilize the normal third conductor (or P-wire) for the transmission of the metering signal from the final selector to the subscriber's line circuit. This P-wire is primarily provided for testing, guarding and holding purposes, and it is a fundamental requirement that, if any metering signal is passed over the P-wire, it must not interfere with the normal circuit operations which take place on this wire. It is still more important that there should be no possibility of false registration of the subscriber's meter during the various phases of testing, switching, etc.

A method of metering over the P-wire, which has been extensively used in the past, is illustrated in Fig. 316. It is known as a *booster metering* scheme, due to the fact that operation of the subscriber's meter is effected by applying an additional or booster voltage to the P-wire.

One side of the subscriber's meter is connected to the normal circuit battery, whilst the other side is connected to the P-wire. During the

process of setting up a call, either an earth or a negative battery potential may be applied to the *P*-wire. The meter is so adjusted, however, that it will not operate with 50 V across its coil, i.e. it will not operate when there is an earth on the

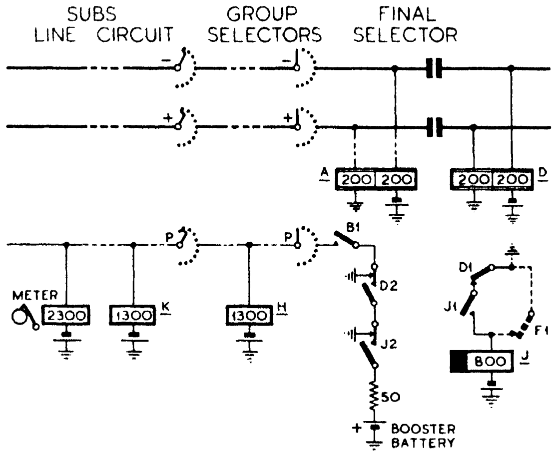


FIG. 316. BOOSTER BATTERY METERING CIRCUIT

P-wire. Metering is accomplished by replacing the earth normally returned from the final selector for holding purposes by a 50 V *positive* battery. This results in a potential of some 100 V across the meter, which now operates. After the withdrawal of the positive battery, the meter holds to the reduced current from the earth on the *P*-wire. It will be noted that the application of a positive booster battery at the final selector merely augments the current in the holding relays (*H*) of the intermediate selectors, and does not therefore interfere with the holding circuit. Unfortunately, the positive potential on the *P*-wire during metering is, in some cases, liable to interfere with the guarding of the circuit against intrusion. For example, the *K* relay in the earth testing circuit of Fig. 256 would tend to operate if the *P* wiper of the switch encountered positive potential. In the same way, any battery testing circuit (e.g. Fig. 262) would switch to such a potential. False switching can be avoided with either type of circuit by the provision of suitably connected metal rectifiers in the switching relay circuit, but, provided the meter pulse is kept as short as possible, the risk of double connexions does not usually justify the expense of providing such rectifiers. It should be noted that the pre-operated type of earth testing circuit (Fig. 259) does *not* switch to a positive metering potential on the *P*-wire.

Apart from the possibilities of false switching to the metering potential on the *P*-wire, it is most undesirable to apply the booster voltage for the duration of a call, owing to the heavy power consumption which would be incurred. The circuit is therefore arranged so that the booster potential is applied to the *P*-wire only for a short period after the called subscriber has answered. Fig. 316 shows a typical arrangement in which relay *D* applies the booster potential to the *P*-wire when the called subscriber answers and, at the same time, breaks the circuit of a slow-to-release relay *J*. After a period of some 300 msec, *J* releases to remove the booster potential from the *P*-wire. The circuit is such that it is impossible to re-apply the metering condition if the *D* relay is flashed during the progress of a call.

One of the difficulties with a booster metering circuit is that the booster potential must be applied before the holding earth is removed from the *P*-wire—if this were not so, the holding relays of the whole train of selectors would be released. This involves the use of make-before-break contacts on relays *D* and *J*, together with a 50 Ω protective resistance in the booster battery supply to limit the value of current during the short period when all three springs of the make-before-break contact units are bunched. Even so, there

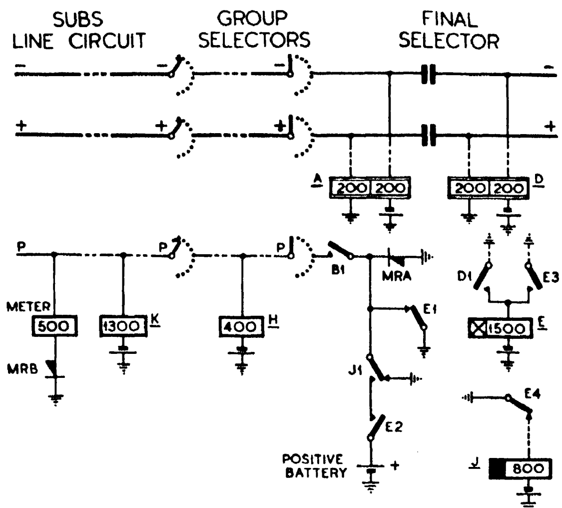


FIG. 317. POSITIVE BATTERY METERING CIRCUIT

is a danger in practice of the *D* or *J* make-before-break contacts welding together due to the comparatively high current when all three springs are in contact. In order to guard against the risk of fire should such a welding occur, it is usual to fit heat coils in the booster battery supply so that the supply is disconnected and an alarm is given,

should an excessive current flow for a predetermined period. It will be clear from Fig. 316 that any disconnexion in the booster battery supply would cause any call to release when the called party replied.

Positive Battery Metering. Booster battery metering has been replaced, in modern exchange circuits, by the positive battery metering scheme illustrated in Fig. 317. The metering condition is, as before, a positive battery on the *P*-wire, but the meter is connected to earth instead of to negative battery as in the booster scheme. A metal rectifier (*MRB*) is connected in series with the meter. The direction of this rectifier is such that it offers a negligible impedance to current from the positive metering battery, but, at the same time, it has a very high impedance to any currents resulting from the negative battery potentials at the various *K* and *H* relays along the *P*-wire.

The provision of rectifier *MRA* in the final selector circuit provides a holding condition on the *P*-wire independent of the metering circuit, so that it is possible to use simple changeover contacts instead of make-before-break contact units in the metering circuit. The direction of this rectifier is such that it readily permits the passage of currents from earth to the negative battery behind the various *H* and *K* relays, but at the same time it offers a high impedance to prevent the shunting away of the positive battery potential during metering.

The circuit is arranged so that relay *J* is pre-operated during the setting up of the call (i.e. when the final selector switches to the called line). When the called subscriber replies, relay *D* operates, and **D1** energizes relay *E*, which has an armature-end slug. After a short period of lag, *E* operates, locks via its own contact ***E*3**, and at ***E*1** removes the earth from the metering circuit. ***E*2** applies the positive metering battery via ***J*1** and ***B*1** to the *P*-wire and so to operate the meter in the subscriber's line circuit. At the same time ***E*4** disconnects the circuit of the slugged relay *J*, and after a lag of some 300 msec *J* releases to remove the metering potential at *J*1. It will be noted that any flick operation of relay *D* does not initiate the metering operation unless the ***D*1** contact is closed for a period equal to the pulse operate time of relay *E*. If ***D*1** is operated for a time greater than this period, then the *E* relay operates and locks, and the metering operation is now entirely independent of the supervisory condition from the called subscriber. Once metering has been effected, it is impossible to re-apply the positive battery to the *P*-wire due to the locking of relay *E*, and the permanent release of relay *J*. The earths at contacts *E*1 and *J*1 short-circuit the rectifier *MRA* before and after the metering operation to exclude the rectifier impedance from the holding circuit. (It is desirable that there should be a low resistance earth potential on the *P*-wire outside the metering period to ensure that the circuit tests engaged to all other hunting selectors.)

It will be noted that the connexions of the subscriber's meter in the positive battery metering scheme do not provide for the locking of the meter after its initial operation. If desired, this facility could readily be provided by connecting the meter as in the booster battery scheme (Fig. 316). The arrangement shown in Fig. 317, however, avoids the use of a meter with marginal adjustments, and also permits of multi-fee metering when used in conjunction with a metering circuit of suitable design.

Multi-fee Metering. The tariff system of the British Post Office permits of calls up to 5 miles radial distance for the unit fee charge. With the continued development of the automatic system in this country, it is the policy that, wherever technical considerations will permit, the subscriber shall be able to dial any required number within a radius of 15 miles. Calls over greater distances are obtained through the automanual operator, and the appropriate charge is entered on the call ticket.

When facilities are provided for the subscriber to dial to exchanges outside the unit fee area, a system for automatically metering the correct fee is required. On any call, the appropriate fee is determined by the radial distance as follows:

Under 5 miles . .	1 unit
5 to 7½ miles . .	2 units
7½ to 12½ miles . .	3 units
12½ to 15 miles . .	4 units

The correct number of meter pulses must be applied at the local exchange, since it would not be practicable to transmit signals back over the junction to indicate the fee for any particular call. Apart from the impracticability of providing such junction signals, there are many cases where the incoming equipment at the distant exchange cannot determine the correct fee since it does not know from which exchange the call originates. The fundamental requirement that the charge must be determined locally involves the provision of fee determination equipment at the originating exchange. This equipment must be located so that it can receive the answering condition when the called party replies in order that the appropriate

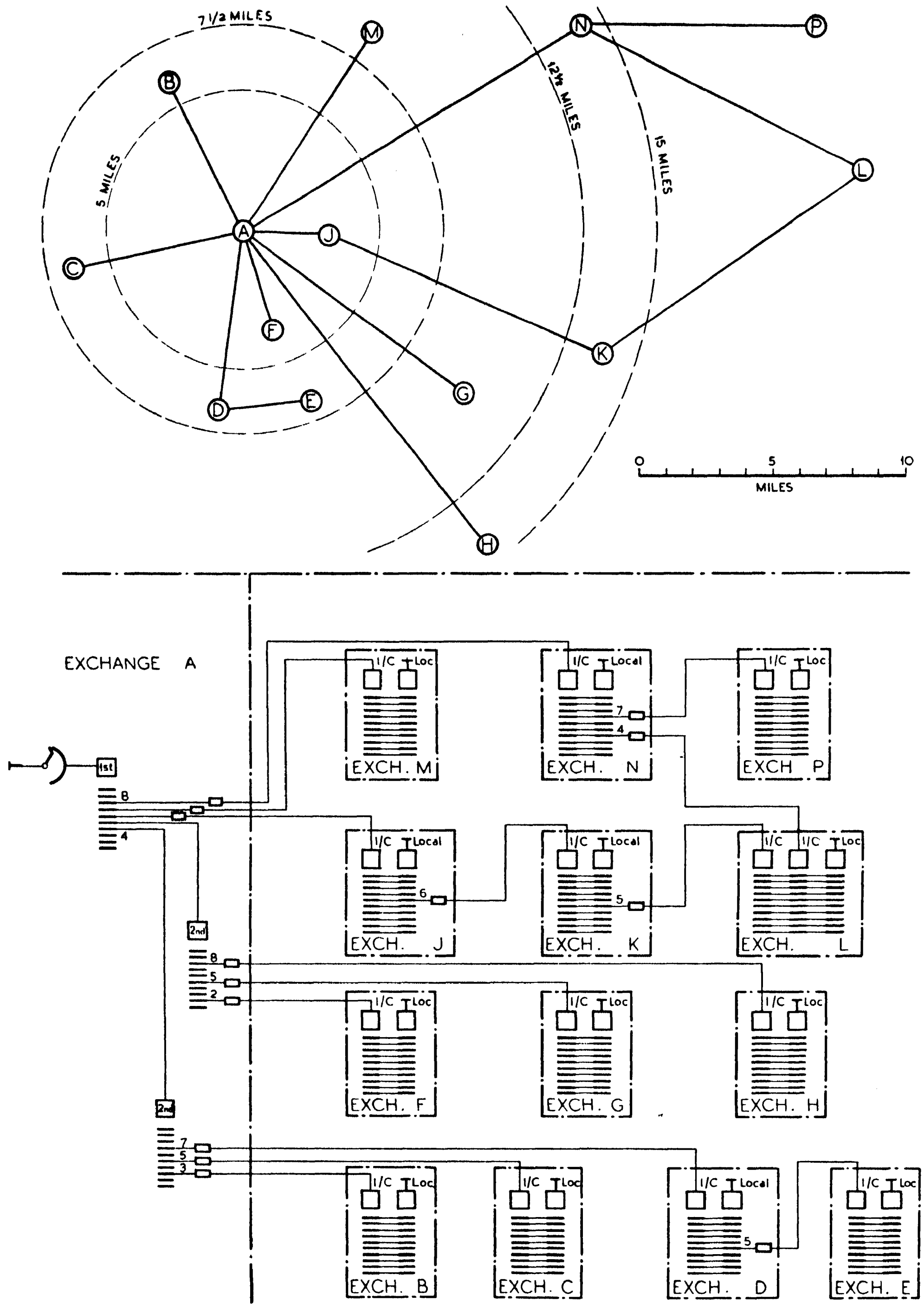


FIG. 318. HYPOTHETICAL JUNCTION NETWORK TO ILLUSTRATE THE PROBLEMS OF MULTI-METERING

number of meter pulses can be applied to the *P* or meter wire, and thence to the calling subscriber's register. It follows that the metering circuit should be closely associated with a transmission bridge or an impulse repetition bridge. The fee appropriate to any particular call must be determined either directly by impulses dialled by the subscriber, or indirectly by the positioning of the automatic switches in the originating exchange.

Fig. 318 shows a portion of a hypothetical junction network. To avoid undue complication, only those circuits required for the setting up of calls from exchange *A* are shown. It will be observed that exchanges *M* and *N* are routed direct from levels 7 and 8 of the 1st selectors at exchange *A*. Exchange *M* is in the 3-unit fee zone and exchange *N* is in the 4-unit fee zone. If the design of the automatic exchange is such as to require outgoing relay sets between the selector levels and the junctions, these relay sets provide a convenient point for the application of the appropriate number of meter pulses. For example, the outgoing relay sets on level 8 can be arranged so that, when the supervisory signal is received from the distant exchange, 4 unit fees are automatically applied to the calling subscriber's meter. Similarly, the relay sets on level 7 can be arranged always to give 3 meter pulses on receipt of the answering condition.

In some exchanges there is an impulse repetition bridge in the 1st selector, and relay sets are not required on the outgoing selector levels. In these circumstances it would be an unnecessary expense to provide an additional transmission bridge on the outgoing levels merely to apply the metering signals. Fee discrimination can, in these circumstances, be provided by relays in the 1st selector which will set up the correct metering conditions, depending upon the *level* to which the 1st selector is stepped, i.e. if the 1st selector is stepped to level 8, the metering circuit will automatically apply 4 pulses to the subscriber's meter on receipt of the answering condition.

Level control of metering at the 1st selector stage can be used only when the junctions are routed direct from 1st selector levels, and when each level gives access only to exchanges of the same fee. In Fig. 318 level 5 is routed to 2nd selectors, and the levels of these 2nd selectors are routed direct to exchanges *F*, *G*, and *H*. It is therefore not possible to determine the fee merely by noting that the 1st selector has been stepped to the 5th level. The correct fee is known only when the 2nd selector has been stepped to seize the required outgoing junction. In cases such as this, the fee determination equipment must be placed in outgoing relay sets from the 2nd selector levels, or in the 2nd selector circuit itself, where the level to which the selector is stepped can be used to determine the correct charge.

Level 4 of the 1st selectors at exchange *A* is also routed to 2nd selectors, from the levels of which junctions are provided to exchanges *B*, *C*, and *D*. These three exchanges are, however, all within the 5–7½ mile belt of exchange *A*, and hence the same fee applies to all. As before, multi-metering facilities can be provided by arranging that the outgoing relay sets on each junction route apply 2 pulses when the call is answered. Alternatively, it is possible to obtain some economies by providing relay sets in the trunks between the 1st and 2nd selectors. By this means the relay sets would be in a common pool and a smaller number would be required than when the relay sets are placed on the individual outgoing routes.

It will be noted that exchange *E* is accessible from level 5 of the 1st selectors at exchange *D*. Hence, by dialling the digits 475, a subscriber on exchange *A* can obtain access to the subscribers on exchange *E*. In this particular case, calls to exchange *E* have a charge value of 2 units, and hence the correct fee is automatically applied at the originating exchange.

The route to exchange *J* from level 6 of the 1st selectors at exchange *A* is rather more complex. Exchange *J* is within the 5-mile circle of exchange *A*, and hence has a chargeable value of 1 unit. Level 6 of exchange *J* gives access to another exchange *K*, which is a 4-unit fee from exchange *A*. Thus, calls leaving exchange *A* from level 6 of the 1st selectors may be either single fee calls or 4-unit fee calls, depending upon whether or not they terminate on exchange *J* or are routed through *J* to *K*. It is clearly not possible to determine the correct fee until the second digit has been dialled by the originating subscriber. In circumstances such as this, it is necessary to provide additional equipment at exchange *A* which will count the impulses of the second digit in order to determine the appropriate fee. The obvious place for this impulse counting circuit is in the outgoing junctions themselves. A fee determination circuit so placed need count only one impulse train (i.e. the second) and can be comparatively simple. As an alternative, equipment could be associated with the 1st selector, which would count the first and second impulse trains and, depending upon the digits dialled, could apply the appropriate meter pulses to the calling subscriber's line. An impulse counting circuit of this type is required only during the setting up of a

call, and it is sometimes wasteful to provide one counting circuit which is permanently associated with each 1st selector. It is generally preferable to arrange for the multi-metering equipment to be temporarily associated with the selector during the setting up of a call, and then to be released for use by other selectors. If the fee determination equipment is placed in the 1st selector, it will be required to count the first and second impulse trains, and hence will be more expensive than a circuit placed on the selector level to count one train only. On the other hand, if a high percentage of the calls from exchange A are to exchanges in the multi-fee range, then it may be preferable to provide fee determination equipment which can be associated with the 1st selector on every call rather than to provide the facilities in the relay sets outgoing from the 1st and 2nd selector levels.

To summarize, there are three fundamental methods of determining the correct fee on outgoing junction calls:

(*a*) To determine the fee from the level to which the 1st or 2nd group selectors are stepped. This method can be used only where all calls passing over that level have the same charge.

(*b*) To provide fixed fee metering conditions in the relay sets associated with outgoing junctions. Here again, fixed fee metering can be used only when all calls passing over that group of junctions are to exchanges of the same chargeable distance.

(*c*) If the final destination of a call is not determined by the time it leaves the originating exchange, it is necessary to provide digit counting equipment which will respond to one or more impulse trains. The positioning of the digit counting switches can then be used to determine the correct fee.

Route Restriction. All except very small automatic exchanges provide facilities for tandem switching, i.e. the exchange is designed so that distant exchanges can obtain the required exchange by dialling through the selectors at some intermediate or tandem point. It is important that irregular use of these tandem facilities should be prevented. In Fig. 318, for example, there is a route from exchange N to exchange P. Facilities are available for subscribers on exchange A to dail exchange N, which is in the 4-unit fee range of A. If a subscriber on exchange A dialled the digit 8 to obtain exchange N, and then followed this by a second digit 7, he could obtain access to exchange P, which is well outside the 4-unit fee range of the originating exchange. If, therefore, a subscriber could find the correct routing code, it would be possible for him to extend a call progressively through various tandem centres to reach an exchange a considerable distance away. Apart from the loss of revenue which would result from calls set up in this way, the irregular use of the various junction groups completely upsets the calculated traffic capacity of each route. Moreover, any call which is not set up over the recognized regular route is liable to dialling and transmission difficulties.

One method of preventing calls from exchange A to exchange P is to disconnect level 7 of the incoming selectors at exchange N which are associated with the junctions from exchange A. In most circumstances this is not a practicable solution, due to the fact that there is usually a large number of incoming selectors from a number of different exchanges, some of which may be permitted to dial exchange P via exchange N. For various reasons, it is desirable to intermix the incoming selectors, and in most circumstances it is not practicable to segregate one or more shelves and to concentrate all the incoming junctions from a certain exchange on these shelves. If level segregation at exchange N is not practicable, then it is necessary to introduce impulse counting equipment at exchange A so that, if the second digit is 7, the junction is automatically released and Number Unobtainable tone is returned to the calling subscriber.

Similar conditions exist in Fig. 318 in respect of level 6 of the 1st selectors at exchange A. Access to exchanges J and K is permissible, but facilities must be provided for preventing the extension of a call via level 5 at exchange K to obtain access to subscribers on exchange L. Here again, impulse counting equipment could be provided on level 6 at exchange A such that, if the third digit is 5, the call is automatically stopped. This involves the provision of equipment which will count both the second and third digits (e.g. 6 and 5).

Exchange L is beyond the 15-mile circle from exchange J, and hence access to exchange L must be prohibited to subscribers on exchange J as well as to those on exchange A. Some economies can therefore be effected in this case by providing equipment on level 6 of the 1st selectors at exchange J such that, if the next digit is 5, the call is prohibited. Such equipment would prevent subscribers on exchange J from obtaining access to exchange L, and would at the same time prevent access from exchange A—thereby saving the impulse counting equipment on level 6 at exchange A.

In practice the junction network is usually considerably more complex than is shown in Fig. 318. In particular there will be junction routes between a number of the various exchanges

B to *P* which may provide irregular routes which must be prevented. One such link route is shown between exchange *N* and exchange *L*. It is clear that the equipment at exchange *A* must not only provide for route restriction if the digits 87 are dialled, but must also prevent access to exchange *L* if the digits 84 are dialled.

The equipment provided to prevent the irregular routing of calls must include impulse train counting switches, and, since similar facilities are often provided for fee determination, it is common practice to combine the fee determination and route restriction equipment into one circuit.

Meter Pulse Machines. The pulses necessary for multi-fee metering circuits can be obtained from a meter pulse machine which is common to the exchange. Two such machines (together with their associated control relays) are shown on the second shelf of the A.E.R. illustrated in Fig. 156.

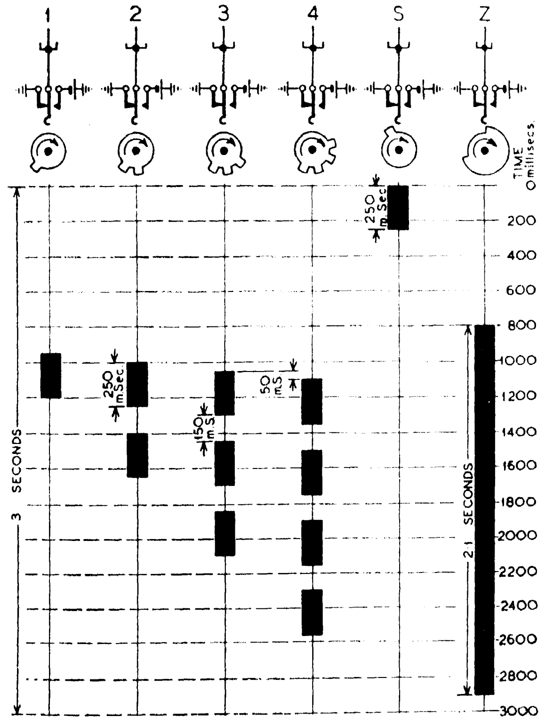


FIG. 319. TIMING OF METER PULSE MACHINE CAMS

The machines are usually designed for operation from the normal exchange battery, and the circuit arrangements are such that, if one machine fails, it is automatically replaced by the second or reserve machine. The spring sets of the machine are controlled by cams fixed to a slow speed shaft which is driven via a worm gear from an electric motor.

One rotation of the slow speed cam-shaft represents a complete metering cycle. During this cycle, one of the cams is arranged to give a single

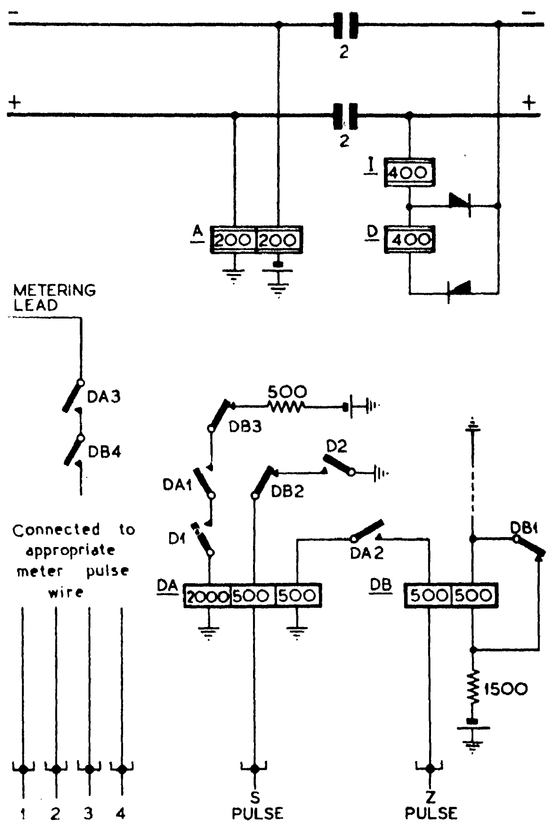


FIG. 320. MULTI-METERING CONTROL CIRCUIT USING *DA* AND *DB* RELAYS

meter pulse of some 250 msec, whilst other cams provide 2, 3, or 4 meter pulses of similar duration with a period of some 150 msec between successive pulses. Two additional spring sets are required on the meter pulse machine to ensure that the meter pulse springs are connected to the metering circuit only at the commencement of a cycle and, once the metering cycle has been started, to guard against any interruption of the metering sequence.

Fig. 319 shows the timing of the various cams. The operation of contacts *S* prepares the selector circuit to receive the meter pulses, but the circuit is not established until the *Z* springs operate some 550 msec later. The *Z* pulse maintains the metering circuit for a period of 2·15 sec, which is sufficiently long for the transmission of the maximum number of meter pulses (i.e. four). The release of the *Z* contacts now disconnects the metering circuit, and so prevents the transmission

of any further pulses to the subscriber's meter during the period of the call. The circuit arrangements are such that, if the meter pulse machine is associated with the selector circuit at any time during the cycle of the pulses, the application of the metering condition is deferred until first an *S* pulse and then a *Z* pulse are received. This system ensures that the meter pulse leads are connected to the metering circuit only at the commencement of the cycle.

for *DB* for the duration of the call. Contacts **DA3** and **DB4** now connect the appropriate meter pulse cam to the selector metering wire. (The method of determining the appropriate fee, and of transmitting the metering signals to the calling subscriber's meter are described later.) The cessation of the *Z* pulse some 2·1 sec later releases relay *DA*, which at *DA*3 disconnects the metering lead. The meter pulse cams are so arranged that, by this time, the full number of

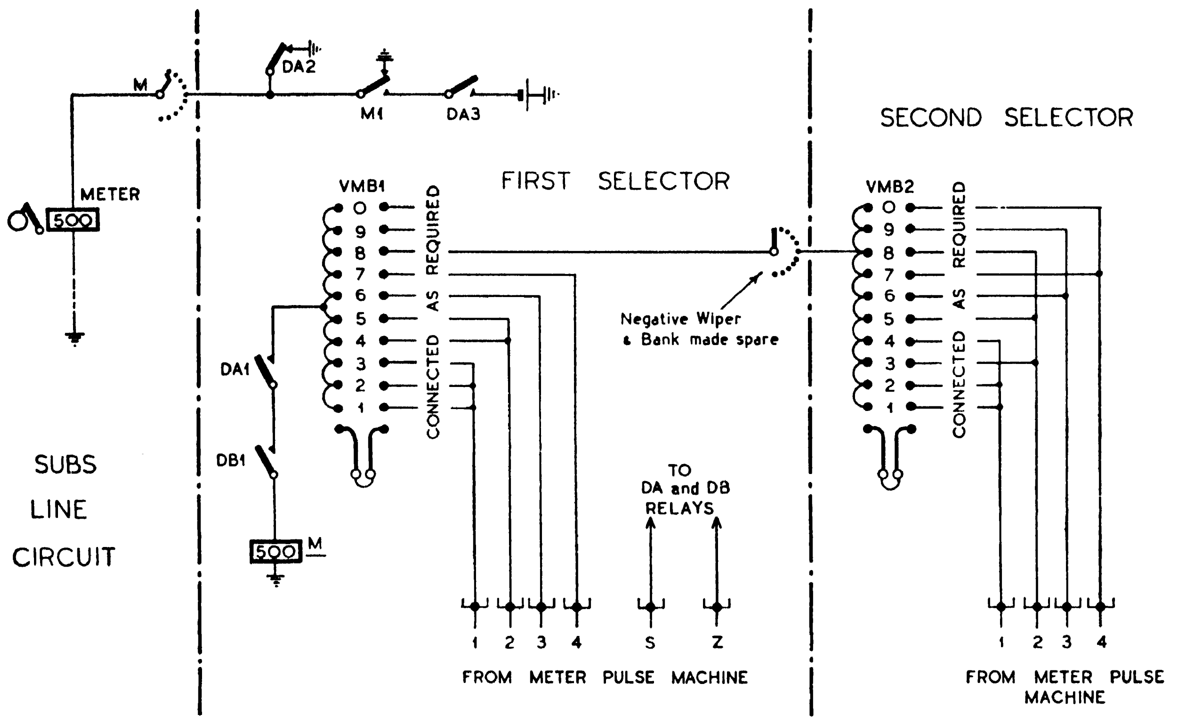


Fig. 321. Level Control of Metering

Basic Multi-metering Control Circuit. The method of applying multi-metering conditions is illustrated in Fig. 320. As before, relay *D* operates when the called subscriber replies and, at **D2**, prepares a circuit for relay *DA*. The first *S* pulse from the meter pulse machine completes the circuit to operate relay *DA*, and contact **DA1** provides a local holding circuit for *DA* independent of the *S* pulse but under the control of *DB*3. **DA2** prepares a circuit for the *DB* relay from the earth on the third winding of *DA*.

In due course, the *Z* springs of the meter pulse machine close and operate relay *DB*. The hold circuit for relay *DA* is broken at **DB2**, but an alternative holding circuit is provided by its third winding, which is connected to the *Z* pulse in series with *DB*. **DB1** provides a locking circuit

metering pulses has been transmitted. Relay *DB* is held until the termination of the call, and at **DB2** prevents any further operation of the *DA* relay on succeeding operations of the *S* cam.

Level Control of Metering. We have seen that, where an outgoing junction route is connected to a particular level of the 1st selectors, it is sometimes possible to determine the appropriate fee by noting the level to which the selector has been stepped. In other cases, junctions are trunked from levels of 2nd or subsequent selectors, and in these circumstances it may be necessary to apply the appropriate fee from the level of the 2nd or 3rd selector. This system of determining the appropriate fee from the selector level over which the call is routed is known as *level control of metering*.

Fig. 321 shows a common arrangement. For

purposes of illustration, it is assumed that the levels of a 1st selector give access to exchanges where the following fees are chargeable:

Level 7 . . .	4 units
Level 6 . . .	3 units
Level 5 . . .	2 units
Level 4 . . .	2 units
Level 3 . . .	1 unit
Level 2 . . .	1 unit
Level 1 . . .	1 unit

After the called subscriber has replied, relay *DA* operates to the first *S* pulse as already described, and prepares the circuit for the *DB* relay. The *Z* pulse operates *DB*, and a circuit is now completed for relay *M* via ***DB*1**, ***DA*1**, and the vertical marking wipers to the appropriate meter pulse lead. If it is assumed that the call is routed over level 7, 4 battery pulses will be extended to relay *M* before relay *DA* releases at the termination of the *Z* pulse.

***DA*2** removes one of the earths applied to the meter wire at the commencement of the metering cycle, and this earth is replaced by positive battery via ***DA*3** during each operation of ***M*1**. Four positive battery pulses are therefore applied to the meter wire before *DA* releases at the end of the *Z* pulse. Contacts *DA*2 and *DA*3 provide adequate safeguards against the accidental operation of ***M*1** during the progress of the call.

Sometimes calls to several exchanges may be routed over the same first selector level, and it is not possible to determine the appropriate fee without a knowledge of the level to which a 2nd selector has been stepped. Second selector level control of metering can be applied in exactly the same way. With a fourth-wire metering scheme, however, an additional wiper and bank is required on the 1st selector to return the metering signals from the vertical marking bank of the 2nd selector. Selectors of a capacity greater than 6 banks are not favoured and, where the 1st selector is of the 200-outlet type, it is necessary to sacrifice the second 10 outlets on any level where 2nd selector control of metering is required. This frees 3 of the wipers of the 1st selector, and it is possible to pass back the metering signal over one of these wipers (usually the negative bank and wiper). The right-hand portion of Fig. 321 illustrates this principle.

Control of Metering from Routing Digits Dialled by Subscriber. In some cases where a call is routed through one or more intermediate exchanges, it may not be possible to determine the correct metering fee, either from the 1st or 2nd selector levels, or from the outgoing route at the originating exchange. In such circumstances, it is necessary to install a circuit which will count the impulses of all or of a number of the routing digits to determine (amongst other things) the correct fee for the call. Fig. 322 shows a typical method of controlling the metering from a digit counting circuit. Three relays are required to provide the necessary combinations to discriminate between 0, 1, 2, 3, and 4 metering pulses. In Fig. 322 the following combinations are used:

No metering .	No relays operated
1 unit fee. .	Relay *MB*
2 unit fees .	Relay *MA*
3 unit fees .	Relays *MA* + *MB*
4 unit fees .	Relays *MA* + *MB* + *MC*

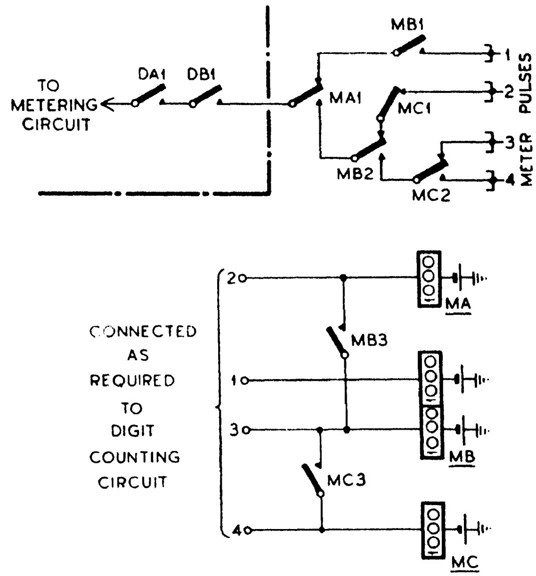


FIG. 322. ROUTING DIGIT CONTROL OF METERING

The required relays are energized from a digit counting circuit such as, for example, the one illustrated in Fig. 247. The selector circuit contains the usual *DA* and *DB* relays and, when the called subscriber answers, contacts ***DA*1** and ***DB*1** apply the appropriate number of meter pulses as determined by the condition of the *MA*, *MB*, and *MC* contacts. For example, if it is necessary to register 2 unit fees, relay *MA* only is operated, and 2 pulses from the meter pulse machine are applied via *MC*1, *MB*2, and ***MA*1** to the metering circuit via the *DA* and *DB* contacts.

Multi-metering Circuit with Uniselector Control. Fig. 323 shows an alternative form of multi-metering circuit which does not require a meter pulse machine or the associated *DA* and *DB* relay

combination. The scheme is of particular application to cases where the multi-metering is controlled from a discriminator, which is either permanently or temporarily attached to the conversational selector. In practice, the meter pulse control

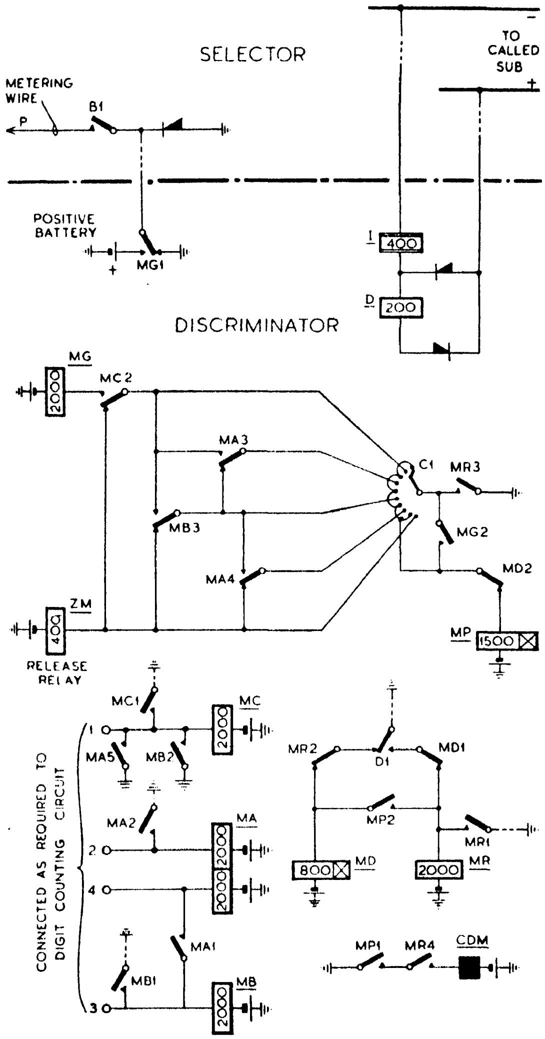


Fig. 323. Method of using Uniselector to Generate and Control Meter Pulses

switch (C) is used also for digit train counting purposes earlier in the progress of the call.

When the called party replies, relay D operates to the loop, and **$D1$** disconnects the circuit of relay MD (pre-operated earlier in the call). Relay MD has an armature-end slug and, after a period of lag, its contacts restore to operate relay MR at $MD1$. MR is provided with a local holding circuit at **$MR1$** and in turn completes a circuit for the MP relay from the earth at **$MR3$** and the first bank contact of the C switch arc. The operation of MP completes the circuit for the C switch driving magnet and re-operates relay MD via **$MP2$**. After the operate lag of relay MD, contact **$MD2$** disconnects the circuit of relay MP, which now commences to release. At the end of the release lag period, the release of $MP1$ steps the C switch to bank contacts No. 2.

Relays MA, MB, and MC have been previously operated and held in accordance with the metering conditions required for the particular code dialled.

The relay combinations are:

1-unit fee call .	Relay MC
2-unit fee call .	Relays $MA + MC$
3-unit fee call .	Relays $MB + MC$
4-unit fee call .	Relays $MA + MB + MC$

Let it be assumed that the discriminator has been set up for a 3-unit fee call. When the C switch wipers are stepped to contact 2, relay MC is operated, and hence relay MG is energized (via **$MC2$**). Contact **$MG1$** connects positive battery to the P-wire to apply a metering signal to the calling subscriber's meter. The release of MP (when the switch steps from the first to the second position) allows MD to release (at $MP2$). On the release of MD, an operate circuit is provided for the MP relay from the earth at **$MR3$** via **$MG2$**. **$MP1$** energizes the C switch magnet, whilst **$MP2$** re-operates relay MD. **$MD2$** again disconnects MP, and, at the end of the release lag, $MP1$ steps the C switch to bank contact No. 3. The circuit for MG is now disconnected at the wiper, whilst the MD relay circuit is broken at contact $MP2$. The release of contact $MG1$ removes positive battery from the metering wire, and the restoration of $MD2$ re-operates relay MP via the third contact of the $C1$ bank.

The above cycle is repeated, the MG relay being operated for a second time via **$MA3$** and **$MC2$**, and for a third time via **$MB3$** and **$MC2$**. When the $C1$ wiper reaches the 8th contact, however, contact $MA4$ is normal, and the earth at **$MR3$** operates the ZM relay to cease the sending of meter pulses and to release the discriminator. If relay combinations had been set up for a single unit fee, ZM would have operated at the 4th step due to the normal condition of contacts $MA3$ and $MB3$. Similarly, if 4 unit fees had been required, the $C1$ switch would continue to step until it reached the 10th contact, when relay ZM would be operated to release the circuit.

Time and Zone Metering. The future tendency

is to permit the telephone subscriber to complete more and more of his calls on a purely automatic basis, i.e. without the aid of an operator. In Great Britain the principle of multi-metering has now been fairly well established. Under this scheme the exchanges surrounding any calling subscriber are zoned, and a fee of 1, 2, 3, or 4 units is charged, depending upon the radial distance of the called exchange. Thus, the system of charging is determined solely by the radial distance, and no cognizance is taken of the duration of the call.

The revenue earning capacity of the common equipment in the various exchanges through which a call passes, and of the junction lines interconnecting the exchanges, is determined by the intensity of traffic flow (in T.U.s). The intensity of traffic flow is, in turn, a product of the number of the calls and the duration of the calls. The longer junction routes and the various switching apparatus involved are fairly expensive, and it seems logical that the subscriber should be charged on some basis which takes into consideration the time of occupancy of the plant. The present system of zone metering provides no inducement for the subscribers to restrict the length of their conversation. (This is a factor of increasing importance as the telephone is used more and more for social purposes.) Moreover, the longer routes are usually made up of small junction groups, and a few prolonged conversations may have a serious effect on the grade of service unless the plant is provided on a very liberal scale.

On local calls (i.e. to subscribers on the same exchange) a material part of the cost of the plant is associated with the individual subscriber's line, and hence there is some argument for retaining a fixed charge per call, irrespective of the duration. On junction calls, however, there is little doubt that the system of charging should be based upon both the distance and the duration of a call. Whilst this principle may be admitted as a theoretical ideal, the question ultimately resolves itself to an economic one, i.e. whether or not the cost of providing time-metering equipment is less than the revenue which would be lost due to the absence of such a facility.

There are various ways in which the amount charged to the subscriber can be made a function both of the distance and of the duration of the calls. It is possible, for example, to replace the present ratchet and pawl type meter by a "motor-meter" mechanism, such as is used for the registration of electric power charges. The meter circuit could be completed when the called party replies, and the value of the current through the meter could be predetermined by the destination of the call (i.e. the current could be stepped up depending upon the radial distance of the call). This method involves the introduction of time metering for all calls (including local calls) and would be rather difficult to superimpose on the *P*-wire of the exchange circuits. Possibly the greatest difficulty, however, is the problem of designing a meter which would be sufficiently inexpensive and compact.

Fig. 324 shows a recent suggestion which is based on present metering technique. The circuit is based on the *DA* and *DB* relay combination, which is a common metering control circuit of the Post Office system, and has been described in earlier paragraphs. In essence, relays *DA* and *DB* operate in turn to the *S* and *Z* pulses from a machine when the called party replies. *DA* is held sufficiently long for the transmission of the maximum number of metering pulses, whilst *DB*, once operated, remains held for the duration of the call. In order to adapt these circuit elements for time metering, it is only necessary to release relay *DB* at the end of each 3 min period so that the metering cycle is repeated for every 3 min of the conversational time. *DB* can readily be released by the application of earth at the appropriate times to the "repeat" lead of Fig. 324.

The provision of a complete timing circuit individual to each conversational link is generally inadmissible on economic grounds. In Fig. 324, 4 miniature relays are provided per selector. These relays are of simple and inexpensive design, and the whole 4 are in fact arranged to mount as a unit in the place of one standard 3000 type relay. It is possible to count the time for which a circuit has been engaged by operating the miniature relays in various combinations. The 4 relays are designated *W*, *X*, *Y*, and *Z*, and together provide a total of 15 combinations. If a means can be found of changing the combination every 12 sec, the unit is capable of counting up to a period of 3 min. In the particular circuit shown, the following timing combinations are employed:

	Minutes	*Seconds*
W	0	0
WX	0	12
WXY . . .	0	24
WXYZ . . .	0	36
WXZ . . .	0	48
WY	1	0
WYZ . . .	1	12
WZ	1	24
X	1	36
XY	1	48

	Minutes	Seconds
XYZ	2	0
XZ	2	12
Y	2	24
YZ	2	36
Z	2	48

The circuit arrangements are such that relays *W*, *X*, *Y*, and *Z* are all normal at the commencement of the timing period. The relays can be operated by the application of a battery potential on one or more of the *W*, *X*, *Y*, and *Z* leads and, when each relay operates, it locks via its own contact to the holding earth (*B*1) in the selector circuit until such time as a short-circuiting earth is applied from the time control circuit.

The 4 leads from the timing group are terminated on 4 separate arcs of a 25-point uniselector. This uniselector is driven round at such a speed that it traverses the whole of the 25 contacts in a period of 12 sec. Thus, the conditions on the *W*-, *X*-, *Y*-, and *Z*-wires are extended every 12 sec to relays *WC* to *ZC* in the common re-setting control circuit. Relays *WC*, *XC*, *YC*, and *ZC* test for the conditions on the *W*-, *X*-, *Y*-, and *Z*-wires, and from this test the appropriate conditions for the next timing period are returned to the selector storage relays.

The re-setting circuit is common to 25 conversational circuits, and is supplied by regular earth pulses every 0·48 sec (i.e. 25 pulses in 12 sec). These pulses operate relay *P* which, at ***P*3** to ***P*6** changes over the *W*-, *X*-, *Y*-, and *Z*-wires from the "test" to the "re-set" circuit, ***P*2** providing a hold circuit for the test relays during the re-setting time. At the end of the time pulse, relay *P* is released and the wipers move on to a new set of bank contacts.

For purposes of description, let it be assumed that the contacts to which the wipers move are connected to a selector where the conversation has been in progress for just under 2 min. The *X* and *Y* relays of this selector are therefore energized (the *XY* combination was set up at 1 min 48 sec), and there is battery potential on the *X*- and *Y*-leads to the uniselector bank and earth potential on the *W*- and *Z*-leads. Relays *XC* and *YC* of the common circuit operate to the battery potentials when the wipers reach this particular set of contacts. Relay *P* now operates and switches the *W*-, *X*-, *Y*-, and *Z*-leads through to a group of *WC*, *XC*, *YC*, and *ZC* marking contacts (***P*2** providing an alternative holding circuit for relays *XC* and *YC*). In this case, the energization of relays *XC* and *YC* applies battery (via ***YC*2**) to the *Z*-lead to operate relay *Z* in the selector circuit. This relay now holds to its local contact.

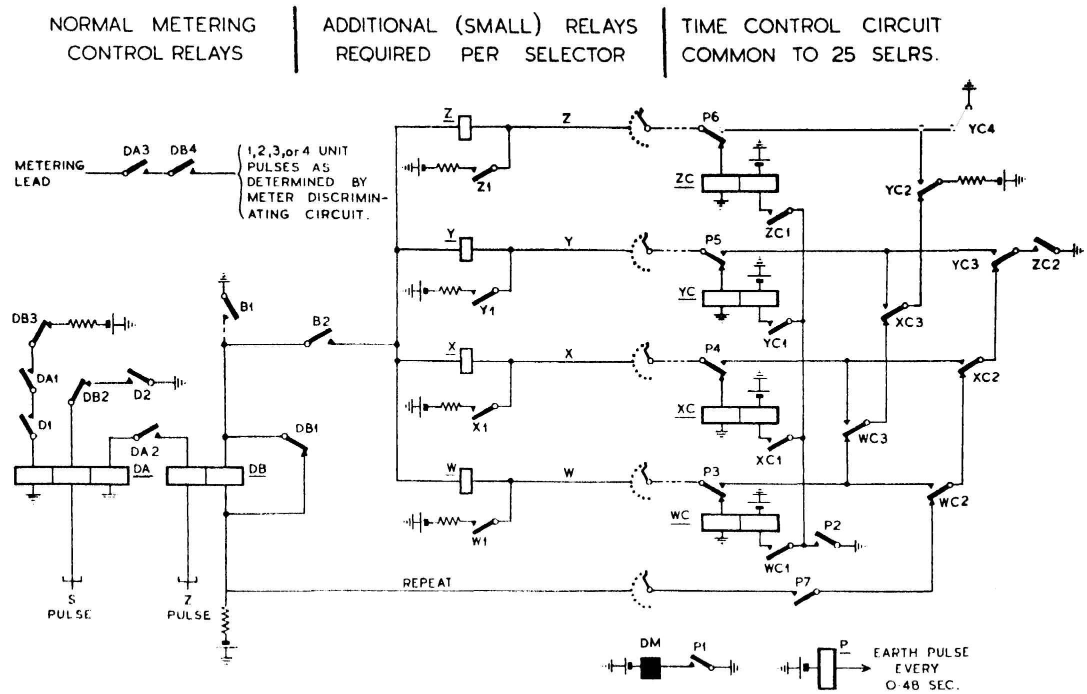


FIG. 324. MULTI-METERING CIRCUIT WITH TIME CONTROL FACILITIES

At the termination of the pulse to the *P* relay, the uniselector steps, and the process is repeated on each set of the uniselector bank contacts.

Twelve seconds later (i.e. some 2 min 12 sec from the commencement of conversation), the wipers return to the above-mentioned circuit and find battery potentials on the *X*-, *Y*-, and *Z*-leads. This permits relays *XC*, *YC*, and *ZC* to operate, and, at the next energization of relay *P*, earth is extended from ***ZC*2** and ***YC*3** to the *Y*-wire to shunt out the *Y* relay in the selector circuit. As the uniselector leaves this contact, therefore, relays *X* and *Z* only are operated to indicate that, when next the uniselector wipers reach this contact, the circuit will have been in use for 2 min 24 sec.

This process continues until, at the end of the 3 min period, the testing circuit finds relay *Z* only operated. ***ZC*2** now extends earth via ***P*7** and the "repeat" lead to shunt out relay *DB* in the selector circuit. The release of *DB* allows *DA* to operate to the next *S* pulse, and the appropriate metering pulses are applied for the second time. This process continues every three minutes until the conversation terminates.

Fig. 324 shows only the basic elements of the time metering circuit. The practical circuit has a number of refinements to prevent unnecessary stepping of the switch when the associated 25 circuits are disengaged, and also to prevent unnecessary operation of the *WC*, etc., relays when the wipers pass over the contacts associated with free selectors. The complete circuit also makes provision for returning a warning signal to the calling subscriber just before the end of each 3 min period. The *YZ* combination in the common re-setting circuit is used to initiate this warning condition. The circuit can, if desired, be arranged to release forcibly any call after a predetermined period.

Metering at Subscribers' Premises. From time to time suggestions have been made for the provision of meters at the subscriber's premises. Such facilities are not available in the Post Office standard system, but it is interesting to examine how such metering can be obtained. Fig. 325 shows a typical circuit in which the metering signal is an alternating current of 50 cycles per second. Relay *P* is connected across the normal subscriber's meter at the exchange, and operates each time metering conditions are applied. Relay *P* has 3 contacts, one of which connects a low voltage a.c. supply derived from the 50 c/s mains via a step-down transformer. The a.c. power is applied

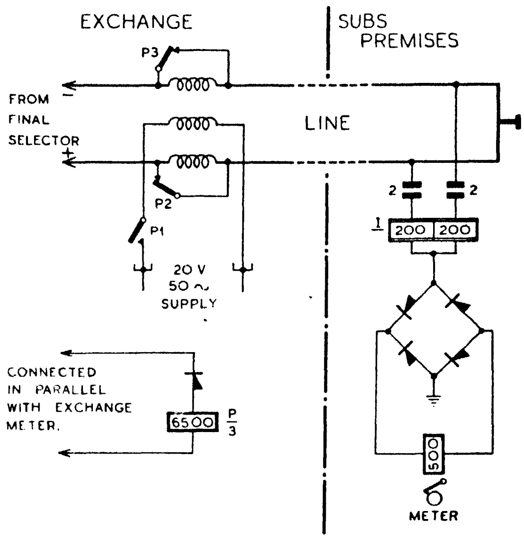


FIG. 325. ONE METHOD OF PROVIDING CHECK METER AT SUBSCRIBER'S PREMISES

to one coil of a 3-winding transformer, the other two coils being connected in series with the subscriber's loop. The operation of relay *P* removes the short circuit from the line coils of the transformer, thereby sending out a 50 c/s metering signal to the subscriber's telephone.

At the subscriber's premises, an impedance coil (*I*) is connected across the speaking pair, suitable capacitors being included to prevent the formation of a d.c. loop. The low-frequency alternating current passes through the capacitors and impedance coil to a bridge connected rectifier, and thence to earth. A meter of the standard pattern is connected across the rectifier and responds to the resultant d.c. potential during metering.

EXERCISES IX

1. In a certain exchange the automatic selectors are held forward from the 1st selector circuit. This selector is required to carry local automatic traffic, and also traffic to a distant manual exchange. Show how you would provide manual hold facilities in the 1st selector circuit. Explain exactly what happens when a subscriber clears after an effective call to another subscriber on the same exchange.

2. Describe, with the aid of simple diagrams, how, on a call to an automatic subscriber, the cord circuit supervisory lamp is darkened when the called subscriber answers. Explain in detail the effects of this supervisory signal on the *A* relay in the automatic exchange final selector.

3. What is the purpose of the "busy flash" signal in an automatic system? Give a diagram of the circuit arrangements at an impulse repetition point which are necessary to repeat the busy flash signal from one side of the bridge to the other.

4. Show, by means of a suitable diagram, how the supervisory signal from the called subscriber can be utilized to operate the meter in the calling subscriber's line circuit over a fourth wire from the 1st selector. What safeguards are provided to prevent irregular operation of the meter?

5. Explain the essential differences between a "booster battery" metering scheme and a "positive battery" metering scheme. What are the relative merits of the two methods?

6. A 50 V non-director 4-digit exchange, with subscribers' uniselectors, is to be equipped for booster battery metering. Determine the value of the common resistance to be inserted in the 50 V positive battery metering lead serving a rack of final selectors, if the current in a subscriber's meter is to be approximately 30 mA, when 10 final selectors served by the common resistance are metering simultaneously. The following resistance values should be assumed:

Subscriber's meter .	2300 Ω
Subscriber's cut-off relay	1300 Ω
Uniselector magnet coils . . .	75 Ω
Joint resistance of selector *H* relay and vertical magnet	1600 Ω

(*C. & G. Telephone Exchange Systems II*, 1948.)

7. A unit fee call between two non-director exchanges is switched over a direct junction line. Give a diagram of the circuit elements concerned with metering the call and describe their mode of operation. (*C. & G. Telephony, Grade II*, 1944.)

8. An automatic exchange (*A*) has direct routes to three other automatic exchanges as follows:

Exchange *B* is situated 4 miles from exchange *A* and the junctions are trunked from level 5 of the 1st selectors at exchange *A*.

Exchange *C* is 8 miles from exchange *A* and is trunked from level 5 of the 1st selectors at exchange *A*.

Exchange *D* is 14 miles from exchange *A* and the junctions are trunked from level 3 of the 2nd selectors connected to level 8 of the 1st selectors.

Draw the elements of a circuit suitable for applying the appropriate number of pulses to the calling subscriber's meter when calls are established over the above junction routes. It may be assumed that all traffic terminates at exchanges *B*, *C*, and *D*.

9. The subscribers on a certain automatic exchange *P* are to be given automatic access to two other exchanges *Q* and *R*. Exchange *Q* is obtained by dialling the single routing digit 7, whilst exchange *R* is obtained through exchange *Q* by following the initial digit 7 by a second digit 6. The appropriate charge for a call from *P* to *Q* is 2d., and the charge for a call from *P* to *R* is 4d. Describe the circuit arrangements at the originating exchange (*P*) which will provide the necessary metering discrimination condition.

10. Discuss the problem of providing metering on a "time" basis for calls over the longer junction routes. When is such a method economically justified and what circuit arrangements are necessary to provide the facility?

CHAPTER X

OTHER COMMON CIRCUIT ELEMENTS

So far we have considered the major signalling and switching functions of an automatic system. Although these impulsing, testing, switching, supervisory, metering, and similar elements are undoubtedly the most important aspects of automatic circuit design, there are nevertheless a large number of miscellaneous circuits of common application which it is desirable to consider before proceeding to a study of the complete selector circuits.

Some of the more important of these miscellaneous circuit elements are examined in this chapter.

Application of Tones. At various stages in the switching operations, it is necessary to transmit to the caller, dial tone, busy tone, ringing tone, or number unobtainable tone (see Chapter I). Until the advent of 2000 type circuits these tones were applied to the speaking wires in one of two ways (Fig. 326):

(*a*) by inserting the secondary winding of a common tone transformer into the earth lead of a suitable transmission bridge relay; or

(*b*) by applying the tone direct or via a capacitor to one wire of the speaking pair.

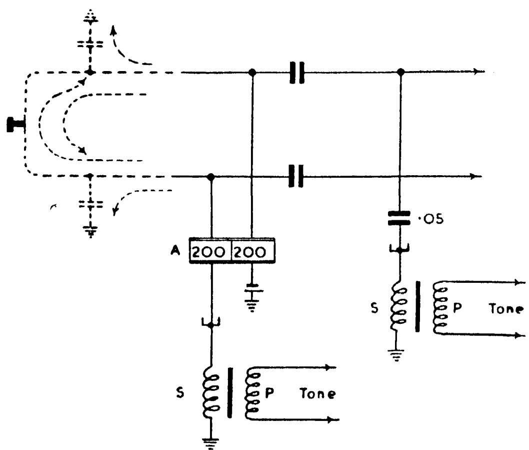


FIG. 326. TYPICAL METHODS OF APPLYING TONES—PRE-2000 TYPE CIRCUITS

The alternating tone current is, in both cases, applied only to one wire of the speaking pair and finds its return path to earth by any available route. It has been found that the absence of a specific return path and the presence of an unbalanced impedance to earth of the two wires tends to promote overhearing between adjacent circuits.

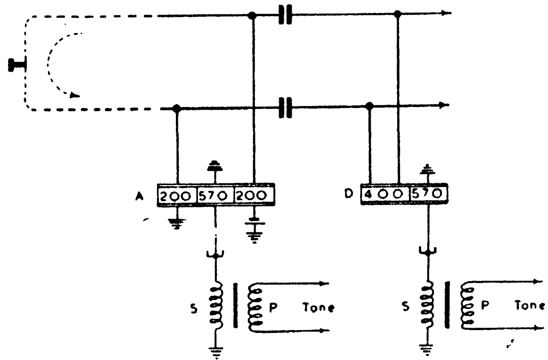


FIG. 327. BALANCED TONES—2000 TYPE CIRCUITS

The difficulties are particularly marked in areas where there are long underground subscribers' lines routed through cables of the star-quad type (the earth unbalance is greater with this type of cable than with the multiple twin formation).

In the latest practice (Fig. 327), the tone is applied to a third winding of the transmission bridge relay. The impedance of each line to earth is now balanced, and the windings of the relay act as a transformer to produce equal and opposite e.m.f.s on the two conductors of the speaking pair. With this method, there is a complete circuit for the tone currents from earth at the bridge relay, round the subscriber's loop, to the battery connexion of the bridge relay. Where it is not convenient to use the transmission bridge relay, the tone can be applied via a special high-impedance relay bridged across the speaking pair as shown at *D* (Fig. 327).

The 200 + 200 Ω bridge windings have approximately 5 times the turns of the 570 Ω tone winding, and hence there is a voltage step up of 5 : 1. This has enabled the voltage of the tone supply to be cut down considerably, which in turn has made it possible to make the common tone transformers of very low impedance. Hence, cross-talk or overhearing in the silent periods of the tone cycle (due to the common impedance) is now practically unobservable.

Dial Tone Circuits. Dial tone (33 c/s continuous tone) is returned to the calling subscriber to indicate that the automatic switching equipment is ready for him to commence dialling. The tone is, of course, necessary to ensure that the subscriber's

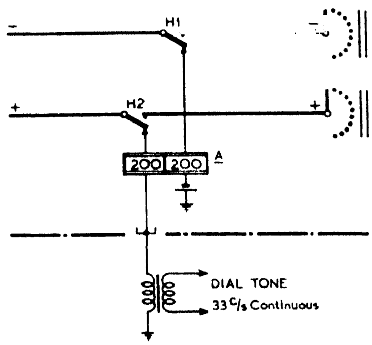


FIG. 328. DIAL TONE CIRCUIT—PRE-2000 TYPE SELECTORS

uniselector (or the linefinder) has switched the calling line to a free 1st selector before the subscriber commences to dial. The circuit arrangements in the 1st selector must, therefore, provide for the return of dial tone to the caller immediately the circuit is seized.

Fig. 328 shows a typical dial tone circuit of a pre-2000 type 1st group selector. The normal earth on one coil of the impulse accepting relay (A) is replaced by earth through the low resistance winding of a dial tone transformer. The second winding of this transformer is connected (through various localizing jacks on the A.E.R.) to the 33 c/s tone generated by the ringing machine. Immediately the subscriber's loop is extended to the 1st selector, dial tone is superimposed on the normal d.c. current. The tone is not removed until the A relay is disconnected from the speaking pair by the operation of the switching relay (H), but from the calling subscriber's point of view the dial tone disappears immediately the dial is moved off-normal during the transmission of the first digit (due, of course, to the shunting of the receiver by the dial off-normal contacts). The dial tone may again be audible to the calling subscriber for the very short period between the restoration of the dial after the first digit and the time when the selector finds and switches to a free outlet. This period is in practice usually so short that the presence of tone is hardly discernible. The dial tone transformer serves a number of 1st selectors, and it therefore forms a common impedance to all circuits served by the same transformer. There is, therefore, a possibility of overhearing between several subscribers who are originating calls at the same time. The danger is minimized by providing a number of dial tone transformers at each exchange, so that there is a definite limit to the number of A relays served by any one transformer.

Fig. 329 shows the dial tone circuit on 1st selectors of the 2000 type. The dial tone is applied to the 570 Ω winding of the A relay, and is transmitted to the calling subscriber by the transformer action of the relay coils. Contact $B1$ is included in the tone circuit to prevent the unnecessary load on the dial tone supply system when the 1st selector is not in use. The tone is first applied when the selector is seized (i.e. when relays A and B have been operated), and is disconnected by the operation of contacts **C1** and **C2** when the selector switches to the next stage. It will be noted that the circuit of the tone coil of relay A is completed throughout vertical stepping. The load on its 570 Ω coil tends to produce a slight slugging effect on the relay. It could be avoided by the insertion of "off-normal" springs in series with the $B1$ contact, but in practice the slugging effect is so slight that this course is not adopted.

All-trunks-engaged Condition. When all trunks on a group selector level are engaged, any searching selector automatically hunts to the 11th rotary step. Busy tone (400 c/s tone for 0·75 sec every 1·5 sec) is now returned to the calling party, and the selector remains on the 11th step until such time as the call is abandoned. As will be seen

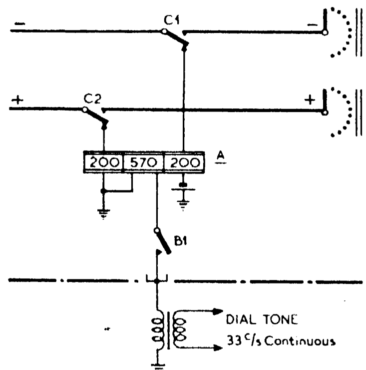


FIG. 329. DIAL TONE CIRCUIT—2000 TYPE SELECTORS

later, it is also usual to provide a meter (*the overflow meter*) on the 11th step bank contacts to record the number of calls which fail due to congestion.

The 11th step P bank contact is therefore connected to battery via a high resistance overflow

meter, but this meter is common to all the selectors in the grading. Hence, any one selector may encounter battery condition (from the overflow meter) on the 11th step or, alternatively, may encounter earth which is applied by some other circuit to operate the meter. It is clearly necessary that group selector circuits should make provision for arresting the rotary drive when the 11th step is reached. Owing to the varying conditions on the 11th step *P* bank, it is not readily possible to utilize the conditions encountered by the *P* wiper for arresting the rotary motion or for setting up the appropriate conditions for the return of busy tone. In practice the correct switching conditions on the 11th step are provided by the use of 11th step cam springs (*S* springs) which operate only when the mechanism is stepped to the 11th rotary position.

Fig. 330 shows the elements of a pre-2000 type selector which provide for the stopping of the drive and for the return of busy tone. If all outlets on the level are engaged, the wipers are stepped to the 11th rotary position, and at this point contacts ***S*1**, ***S*2**, and ***S*3** operate. ***S*2** provides an earth to prevent the operation of the switching

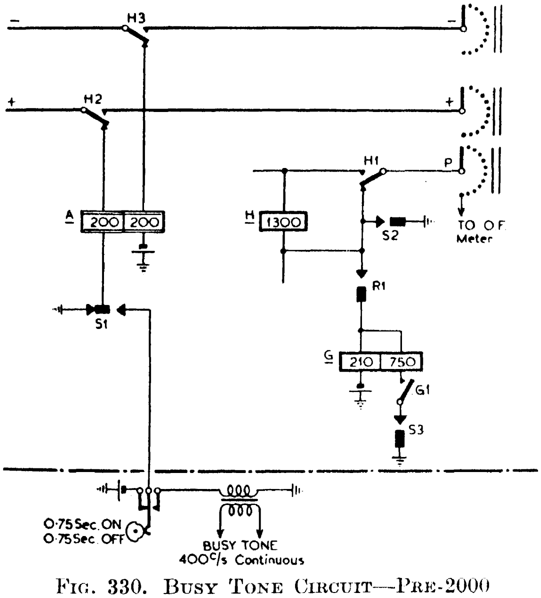


FIG. 330. BUSY TONE CIRCUIT—PRE-2000 TYPE GROUP SELECTOR

relay, and also to operate the overflow meter on the 11th step *P* contact. Relay *G* operates to this earth when the rotary magnet springs (***R*1**) make at the 11th step. Once operated, *G* holds over a local circuit provided by ***G*1** and ***S*3**, thereby preventing any further energization of the rotary magnet. Contacts ***S*1** replace the normal earth on one coil of the *A* relay by an earth through the busy tone transformer and the slow speed interrupter springs of the ringing machine. It will be noted that the tone circuit is combined with the

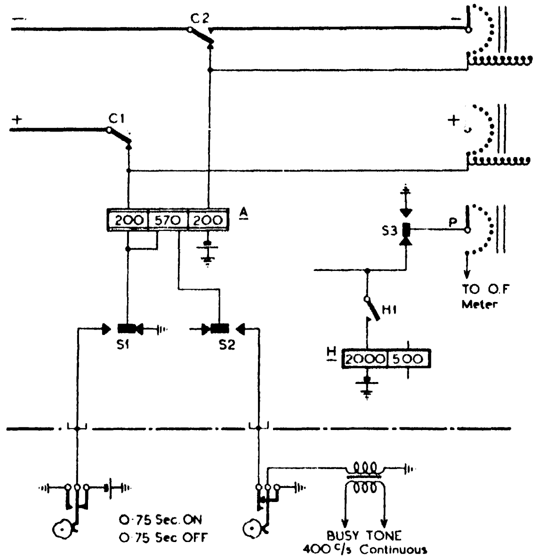


FIG. 331. BUSY TONE CIRCUIT—2000 TYPE GROUP SELECTOR

busy flash circuit already described in Chapter IX (see Fig. 310). As in the case of dial tone, one winding of the busy tone transformer is a common impedance to all circuits connected to busy tone at the same time. The danger of overhearing is, however, not so great in this case owing to the greater masking effect of the 400 c/s tone.

Fig. 331 shows the equivalent circuit arrangements of a 2000 type selector with a pre-operated type testing relay (see Fig. 260). A somewhat different principle is employed in this case. Whereas in the pre-2000 type circuit (Fig. 330) the switching relay is prevented from operating, the 2000 type circuit is arranged so that the testing relay releases just in the same way as it would to a disengaged outlet. The release of the testing relay allows the switching relay (*C*) to operate in the usual way, but continuity of the *A* relay circuit is maintained via the − and + wipers and the 11th step bank contacts.

When the switch moves to the 11th rotary position, contacts ***S*3** operate to break the holding circuit of relay *H* and to apply earth to the *P* bank for the operation of the overflow meter. Contacts ***S*2** connect busy tone via the slow speed interrupter springs of the ringing machine to the 570 Ω winding of relay *A*, and the tone is transmitted

to the caller by the transformer action of the A relay windings. Contacts $S1$ are required for the transmission of busy flash to a manual exchange operator as described in Chapter IX (see Fig. 310).

It will be noted that the busy tone interrupter springs are of the make-before-break type. This is necessary to maintain the holding circuit of relay A during the transit time of the busy flash spring set. (The A relay is held during this transit time from the earth at the busy tone transformer via $S2$, the 570 Ω winding of A, the 200 Ω winding of A, + line, subscriber's loop, − line, and the remaining 200 Ω coil of relay A.)

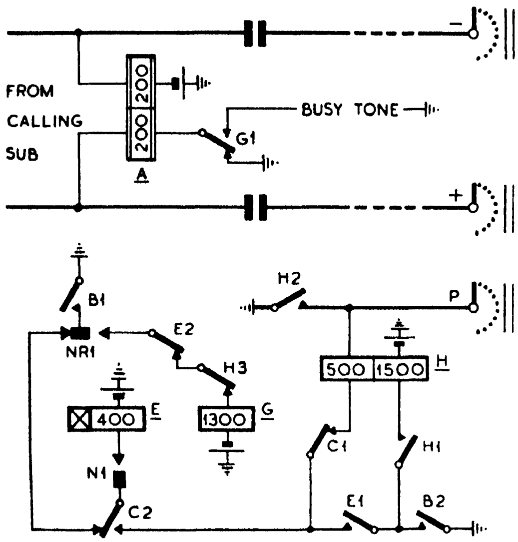


FIG. 332. RETURN OF BUSY TONE WHEN CALLED SUBSCRIBER IS ENGAGED (PRE-2000 TYPE CIRCUITS)

Called-subscriber-engaged Condition. The final selector of a switching train responds to the last two digits of the called subscriber's number which position the wipers on the bank contacts of the required subscriber's line. At the end of the rotary impulse train, the switching relay of the final selector is applied to the P-wire of the called line, and, if the line is free, switching takes place and the call is established. If, on the other hand, the line is engaged, the conditions are such as to prevent the operation of the switching relay, and the circuit must be arranged so that the failure of the switching relay to operate automatically returns busy tone to the caller.

One method of achieving this would be to apply busy tone to the speaking pair at the same time as the switching relay tests the required line. If the line were free, then the switching relay could be arranged to disconnect the busy tone almost immediately after its application but if, on the other hand, the line were engaged, the continued non-operation of the switching relay would allow the busy tone to remain. If this scheme were adopted, a subscriber could dial an engaged number and could wait until the called subscriber's line became free. Busy tone would be encountered for so long as the line were engaged, but as soon as the circuit became free the switching relay would operate and would establish the call.

There is a number of disadvantages in the adoption of this principle. It would, for example, materially increase the quantity of switching equipment required and would introduce difficulties in respect of double switching. It is the policy of the Post Office to arrange all circuits so that, if the engaged condition is encountered at the first attempt, busy tone is returned to the calling party until such time as the call is abandoned, and irrespective of whether or not the required line becomes disengaged in the meantime.

In order to conform with the above policy, final selector circuits are designed so that, if the switching relay does not operate within a specified period (usually about 200 msec), busy tone is returned to the caller until such time as the connexion is released.

Fig. 332 shows a typical busy tone switching circuit of the pre-2000 type. The E relay is part of the impulsing circuit and is provided to effect the changeover from vertical to rotary movement (see Chapter V). By making the E relay slow to release, the circuit can be so arranged that, at the end of rotary impulsing, the release of the C relay applies the H relay to the P-wire and at the same time disconnects the circuit for relay E. If the switching relay is not operated by the time the E relay restores to normal after its period of lag, a further relay G is energized and remains held until the call is released.

The detailed circuit operation of Fig. 332 is as follows. Relay C releases at the end of the vertical impulse train and completes a circuit for relay E from the earth at $B1$ via $NR1$, $C2$, and $N1$. Contacts of the E relay (not shown) now re-energize relay C, and the latter remains held during the rotary impulse train due to the pulses of current in its low resistance winding. During this period, relay E is maintained via $N1$, $C2$, and $E1$ to the earth at $B2$. At the termination of impulsing, relay C releases and at $C2$ disconnects the circuit for relay E. At the same time an earth is applied from $B2$ via $E1$ and $C1$ through the 500 Ω coil of H to the P-wire. If the line is free, relay H operates and locks via $H1$ but if, on the other

hand, the line is engaged, relay *H* cannot operate, and in due course *E*2 restores to complete a circuit for the operation of relay *G* from the earth at ***B*1** via ***NR*1**, *E*2, and *H*3. ***G*1** returns busy tone to the calling subscriber very much in the same way as the tone is applied by the 11th step contacts (*S*) in group selectors (see Fig. 330). It will be noted that relay *G* is held until contact *B*1 releases when the call is abandoned.

The switching time of a final selector *H* relay is fairly long—due partly to the heavy spring load and partly to the fact that it must operate in series with the *K* relay of the subscriber's line circuit. It is important that the release lag of *E* should be sufficiently great to allow relay *H* to operate with a reasonable margin of safety under all conditions. The most severe condition occurs when the wipers are stepped to the first rotary position. In these circumstances the *E* relay is energized only for a very limited period before its circuit is disconnected by the release of *C*2 after a short rotary impulse train. Due to this short period of energization, the full release lag of relay *E* is not obtainable and hence the time available for the *H* relay to switch is small.

Fig. 333 shows the equivalent 2000 type busy switching circuit element. The principle is substantially similar to the pre-2000 type circuit already considered (Fig. 332), except that the total period for which the switching relay is applied to the required line is made somewhat greater by the inclusion of the operate lag of the *C* relay in the timing element.

At the end of the rotary impulse train, relay *C* releases due to the cessation of pulses in its low resistance coil. The restoration of *C*2 breaks the circuit of relay *E* and, after a delay period, *E* restores and completes the circuit for relay *G* from the earth at ***B*1** via ***N*1**, ***NR*2**, *E*3, and *H*3. If the *H* relay has not switched by this time, the *G* relay operates and at ***G*1** and ***G*2** returns busy tone to the calling subscriber. The release of contact *E*2 also allows the re-operation of relay *C*, and, after a short lag, **C1** disconnects the testing winding of the *H* relay. The total period for which the 900 Ω winding of the *H* relay is applied to the *P*-wire of the required line is therefore equal to the release lag of relay *E* plus the operate lag of relay *C*.

It may so happen that the required line becomes free fairly late in the release lag period of relay *E*. In this case there is a possibility of the *H* relay operating after the operation of relay *G*. This is no disadvantage since, under these circumstances, contact ***H*3** will disconnect and release relay *G* before the return of busy tone can be detected by the calling party.

The 2000 type circuit is somewhat better than the pre-2000 type circuit on calls routed to the first contact in any level. It has already been seen that under these conditions the release lag of the *E* relay may be small due to its short period of energization. The addition of the operate lag of relay *C* in the 2000 type circuit ensures that

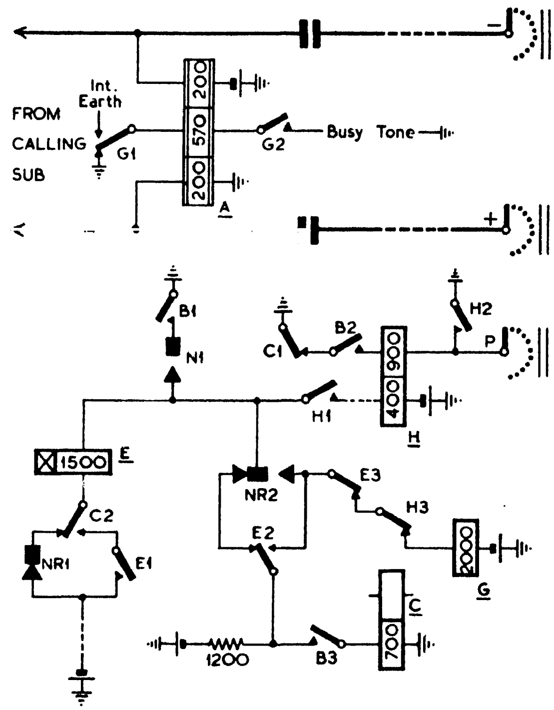


Fig. 333. Return of Busy Tone when Called Subscriber is Engaged (2000 Type Circuits)

the total testing period is adequate even under the most adverse conditions.

Ringing and Ring-trip Circuits. When a call has been set up, it is necessary automatically to apply ringing current to the called subscriber's line, to disconnect the ringing current when the subscriber answers, and to complete the speech path. A circuit extensively used in early automatic systems is shown in Fig. 334. When a selector switches to a free line, 17 c/s ringing current is applied via the 200 Ω winding of relay *F* to the negative line. A return path for the current is provided by the 200 Ω battery on the positive line. Relay *F* is fitted with an armature-end slug so that the alternating ringing current produces eddy currents in the slug which, in turn, oppose the magnetization of the core. The relay is designed so that under the most adverse conditions (e.g. a short leaky

line with several bells in parallel) the resultant flux in the core is insufficient to operate the relay.

The ringing supply is connected to earth but direct current cannot, at this stage, pass due to

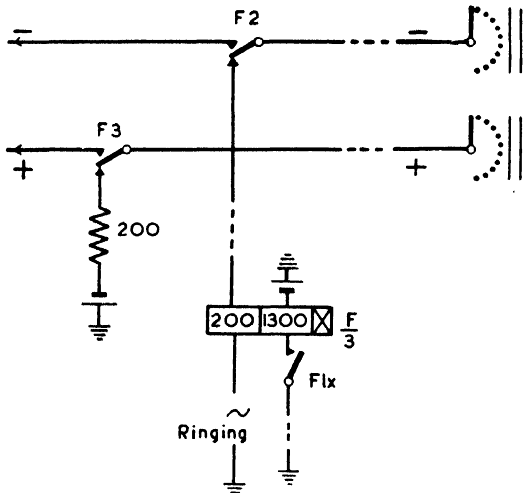


FIG. 334. EARLY FORM OF RING-TRIP CIRCUIT

the blocking capacitor in the subscriber's instrument circuit. When the subscriber answers, the lines are looped for direct current which flows

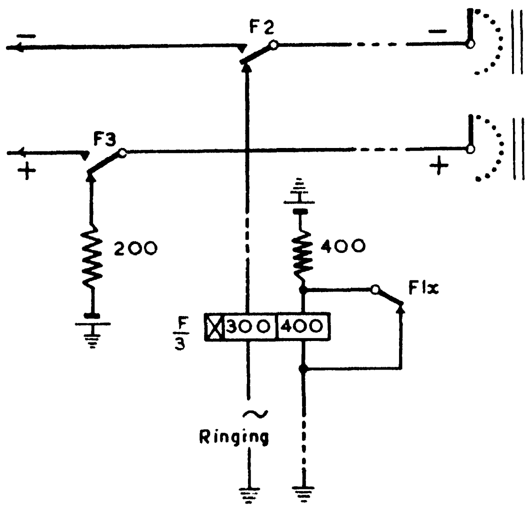


FIG. 335. MODERN RING-TRIP CIRCUIT

through relay F to the 200 Ω battery on the positive wire. F now operates and at **F1** provides a locking circuit. **F2** and **F3** disconnect the ringing circuit and switch through the lines for conversation. **F1** is adjusted to close before the remaining contacts to ensure that the hold circuit is complete before **F2** and **F3** disconnect the initial operating circuit of F.

With the circuit of Fig. 334 difficulties were encountered in practice due to the very close operating and non-operating conditions imposed on the F relay. On the one hand, the relay must be sensitive enough to operate to a subscriber's loop of the maximum resistance during the silent period between the ringing pulses (i.e. without the assistance of the ringing current). On the

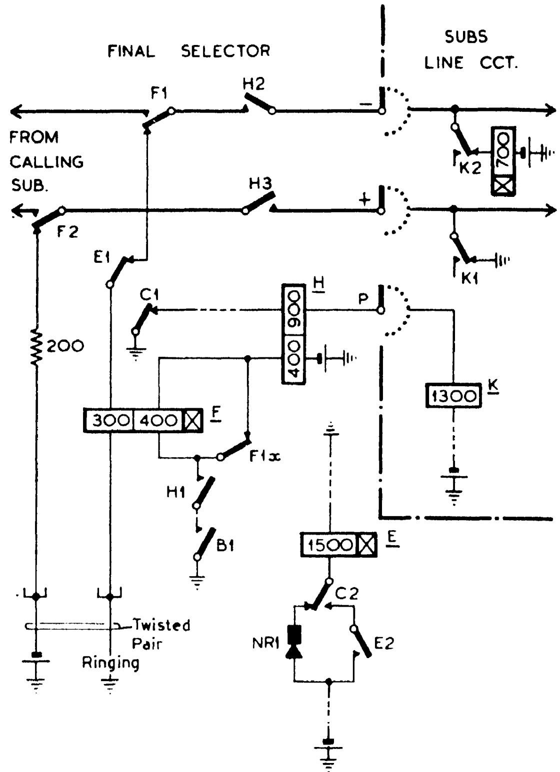


FIG. 336. COMPLETE RINGING AND RING-TRIP CIRCUIT OF FINAL SELECTOR (2000 TYPE CIRCUITS)

other hand, the relay must not operate on a line of negligible resistance and maximum leakance which is terminated by several bell circuits in parallel. With slight mal-adjustment of the relay, therefore, there is a danger either of premature tripping of the ringing or of complete failure to trip.

The margins of the F relay can be materially increased by arranging for the locking winding to be *short-circuited* prior to the operation of the relay. By this means, additional eddy currents are introduced which still further reduce the magnetization of the relay due to ringing current. Fig. 335

shows a modern ringing circuit with this arrangement. The *F*1 contact is now of the break type, and a protective resistance is inserted to prevent short-circuiting of the battery.

Fig. 336 shows the application to a final selector circuit of the principle illustrated in Fig. 335. Relay *E* operates on the release of relay *C* at the end of the vertical impulse train, and, when the *C* relay is re-energized during the reception of the rotary impulse train, the circuit of the *E* relay is maintained by contacts **C2** and **E2**. At the end of rotary stepping, the *C* relay releases and at *C*2 disconnects the circuit of relay *E*—(the ***NR*1** springs are broken at the first rotary step). At the same time, contact *C*1 applies the switching relay *H* to the *P*-wire of the called subscriber's line.

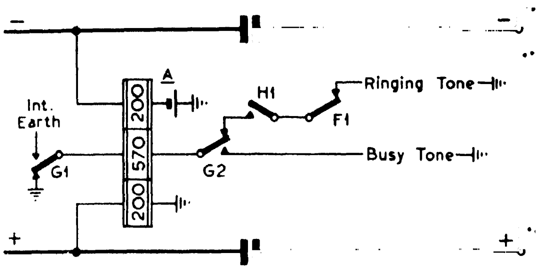


Fig. 337. Complete Tone Circuit of Final Selector Showing Control of Ringing and Busy Tone

If the line is free, *H* operates and at ***H*1** provides a holding circuit for itself from the earth at ***B*1** via contact *F*1 and the 400 Ω coil of *H*. Contacts ***H*2** and ***H*3** switch through the — and + lines, but the ringing current is not applied until contact *E*1 restores when relay *E* releases. This delay in the application of ringing current is necessary to ensure that the switching relay *K* of the called subscriber's line circuit has time to remove the line relay from the negative speaking wire before ringing current is applied. Otherwise the presence of this battery connected relay would cause premature tripping of the ringing current.

With the circuit arrangements shown, there is a time delay between the operation of the switching relay *H* and the application of the ringing current which is equal to the release lag of relay *E* minus the operate lag of relay *H*. Relay *K* in the subscriber's line circuit operates substantially at the same time as relay *H*, and hence the margin of safety is roughly the difference between the release lag of relay *E* and the operate time of relay *H*. In normal circumstances an adequate margin is easily obtainable. In some cases, however, the release of relay *E* completes (for other reasons) the circuit of a further slow-to-operate relay. When these conditions exist, the margin of safety can be further increased by substituting a make contact of the latter relay in place of contact *E*1 in Fig. 336.

The circuit is arranged so that the 400 Ω holding coil of relay *H* provides the necessary protective resistance in the holding circuit of the *F* relay prior to the opening of contact ***F*1*x***. Apart from the saving of a resistor, this arrangement provides an automatic means of decreasing the holding current of relay *H* subsequent to the operation of *F*. The inclusion of the 400 Ω hold coil of *F* in series with the holding winding of relay *H* reduces the current drain during the conversational period and also reduces the release lag of *H* on the release of the call. The inclusion of the *H*1 contact in the ringing circuit guards against premature operation and locking of the *F* relay.

It should be noted that the battery required in the ringing current return circuit is not taken from the normal battery supply to the selector. The *ringing return battery*, as it is called, is wired out to a separate jack point of the selector so that it can be run as a twisted pair with the ringing lead back to the power board, where the ringing fuses are located. This scheme is adopted to prevent interference with speech conductors from an isolated conductor carrying ringing current.

Application of Ringing Tone. Ringing tone is returned to the calling party when the final selector switches to the required line and is withdrawn when the called party answers. Fig. 337 shows a typical ringing tone circuit of a 2000 type final selector. Contact ***H*1** closes when the final selector switching relay operates to the battery on the *P*-wire of a disengaged line. A circuit is now provided from earth through the ringing tone transformer, *F*1, ***H*1**, *G*2, the 570 Ω winding to earth at *G*1. Ringing tone is returned to the caller by the transformer action of the *A* relay windings.

When the called party replies, the ring-trip relay (*F*) operates to the d.c. loop of the called telephone and at contact ***F*1** disconnects the ringing tone. The *F* relay is energized for the duration of the call. The *G*1 and *G*2 contacts are included in Fig. 337 as a matter of interest to show how the busy tone and ringing tone circuits are combined.

Application of Number Unobtainable Tone to Spare Lines. It is usual to connect all spare or unallocated final selector multiple numbers to number unobtainable tone (N.U.T.). Fig. 338 shows the main features of the N.U. tone circuit for spare lines. One 1300 Ω winding of relay *TS*

together with one NU relay is provided per 100 lines of the exchange multiple. The TS relay has, in practice, 4 windings each of which serves 100 lines, i.e. one TS relay will serve a total of 400 lines. The $-$, $+$, and P-wires of the N.U. tone

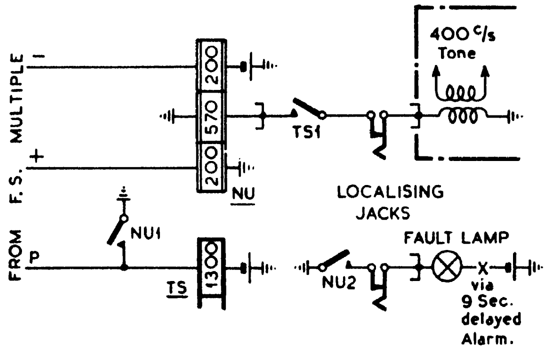


Fig. 338. Method of Applying Number Unobtainable Tone to Spare Lines

equipment are multipled as required to all spare lines in the group of 100.

If one of these lines is dialled, the final selector switches to the battery at the TS relay, and the ring-trip relay of the final selector is operated from the battery on the negative wire at the NU relay. Contact ***TS*1** applies N.U. tone to the 570 Ω winding of NU and thence through the transformer action of the windings to the calling party. It will be noted that the circuit is arranged so that relay NU does *not* operate on a normal call. It is important that the $-$ and $+$ lines of the spare line equipment should not become short-circuited due to fault conditions. A short circuit at this point would provide a loop to operate the supervisory relay (D) of any final selector seizing the circuit, and the call would consequently be falsely registered against the calling party.

The NU relay is provided to give an alarm should the above condition exist. A loop or short circuit on the $-$ and $+$ lines operates relay NU, and the circuit is engaged to all final selectors by the application of earth to the P-wire at ***NU*1**. ***NU*2** lights a local fault lamp, and the circuit includes a supervisory relay which brings in the main exchange alarm system through a 9 second delay circuit. Attention is therefore drawn to any fault conditions on the N.U. tone equipment, and the localizing jacks facilitate the tracing of the faulty circuit.

Treatment of Spare Group Selector Levels. All unequipped levels of group selectors must also be provided with equipment so that N.U. tone is returned to any caller who erroneously dials a spare level. Fig. 339 shows the main features of a spare level N.U. tone circuit. The arrangements are for a 2000 type exchange, but the pre-2000 spare level circuit is substantially similar. When the circuit is seized by a searching group selector, relay A operates from the extended subscriber's loop. ***A*2** holds B which at ***B*1** returns earth on the P-wire to hold all previous selectors (assuming backward holding). ***A*1** applies N.U. tone to the 570 Ω winding of the A relay, whilst ***B*2** lights the various supervisory lamps.

It is uneconomical and indeed unnecessary to provide one circuit per outlet on all spare levels. The number and average holding time of calls routed to such spare levels are usually small. The normal practice is, therefore, to equip from, say, 3 to 9 such circuits for the whole exchange and to multiple the circuits to the first choices of all spare levels, the remaining outlets of each level being engaged. It should be noted that, in the exceptional event of all N.U. tone circuits being engaged, the hunting selectors will rotate to the 11th rotary step and *busy tone* will be returned to the caller.

Permanent Loop Conditions. Low insulation or earth faults on a subscriber's line may permit of sufficient current to operate the line relay at the exchange. This in turn causes the subscriber's uniselector to seize a free 1st selector. It has been seen that the number of 1st selectors provided at any given exchange is determined by the volume of the busy hour traffic. If a number of 1st

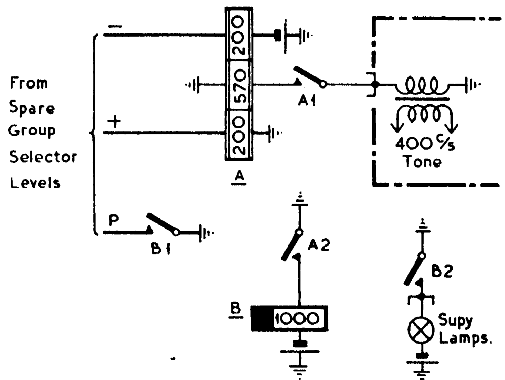


Fig. 339. Method of Applying Number Unobtainable Tone to Spare Group Selector Levels

selectors is falsely engaged due to line faults or for any other reason, then the reduction in the number of available 1st selectors may be sufficient to cause a material degradation in the grade of service. The false seizure of a 1st selector, due to a line fault or any other cause, is commonly known

as a *permanent loop* (P.L.) or *permanent glow* (P.G.) condition. It is usual to provide a supervisory circuit on all 1st selectors so that a visual and audible alarm is given if the selector is seized but is not stepped within a reasonable period.

Fig. 340 shows a typical P.G. alarm circuit. The selector alarm circuit is completed by the operation of contact *B*1 when the circuit is seized, and on regular calls is disconnected by contacts *N*1 at the first vertical step. The battery supply to the P.G. alarm lamp is fed via a 5 Ω supervisory relay (*LA*) which is common to two shelves of 1st selectors. The contacts of *LA* are connected to a suitable delay circuit which is so arranged that, if relay *LA* is energized continuously for a period of 6 min, then shelf, rack and section alarm lamps are lighted. By means of the lamps, it is readily possible to locate the selector concerned and then to trace back the connexion to ascertain the number of the calling line. The P.G. condition is then removed by plugging-up or otherwise disconnecting the faulty calling condition from the exchange.

As stated above, the prime purpose of providing a P.G. alarm is to prevent a degradation in the grade of service due to irregular occupancy of the 1st selectors. Fundamentally these requirements can be met by providing an alarm when the *number* of selectors irregularly held by P.G. con-

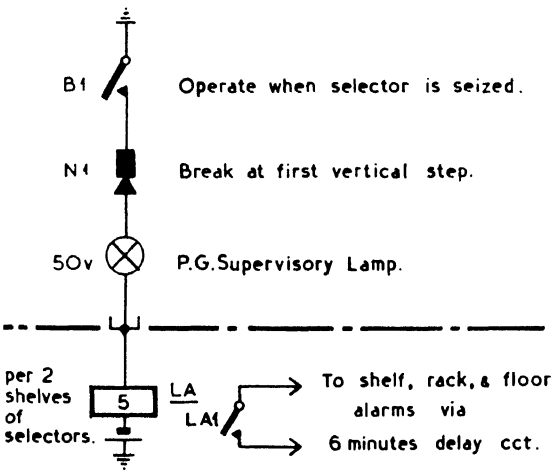


FIG. 340. PERMANENT LOOP ALARM CIRCUIT

ditions is sufficient to produce a material reduction in the grade of service. In a small exchange where there are, say, only fifty 1st selectors, then it may be desirable to give an alarm when five of these selectors are held by P.G. conditions. If, on the other hand, there are, say, three hundred 1st selectors, the engagement of five of these by P.G. conditions would not materially degrade the service. In such circumstances it may be possible to permit the number of selectors held by P.G. to rise to, say, twenty before it is necessary to give

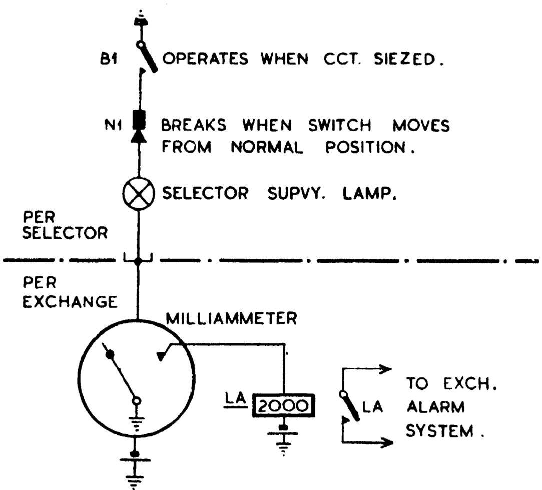


FIG. 341. ALTERNATIVE METHOD OF PROVIDING PERMANENT LOOP ALARM

attention. The tracing of individual P.G. cases—even if they have been existing for an appreciable time—is wasteful of time if there are plenty of other selectors available to carry the traffic at that period. It is therefore unsound to give a P.G. alarm merely because the condition has existed for a predetermined period of, say, 6 min. The ideal scheme would be one in which the P.G. alarm condition is given only when the grade of service is beginning to suffer. For such a scheme it would be necessary to measure the volume of traffic through the exchange at any particular time by noting the occupancy of the late-choice trunks from the subscriber's uniselector. Heavy traffic on the late choices of the grading coupled with P.G. conditions on the 1st selectors could then be used to give a suitable alarm.

An alternative method is to determine, for each particular exchange, the critical number of 1st selectors which can be irregularly held before the grade of service begins to deteriorate. This critical figure would be different for each exchange and would be dependent upon the total number of 1st selectors which are available, and the grade of service given by these selectors during the busy hour. Once the permissible number of P.G. cases has been determined, then it is merely necessary to provide a circuit which will give an alarm when the total number of selectors seized, but not stepped, exceeds this critical figure. Fig. 341

shows such a circuit. Contact *B*1 operates when the selector is seized and completes a circuit for the selector supervisory lamp from a battery obtained via a low resistance milliammeter (common to the exchange). This milliammeter is provided with an adjustable contact which can be set as required to give the alarm when the current through the meter reaches a specified figure. When the selector is stepped from normal, contacts *N*1 open and disconnect the lead to the common milliammeter. Contacts on the meter are arranged to operate a relief relay (*LA*), and the contacts of the latter are extended to the exchange alarm system.

It will be noted that in both Fig. 340 and Fig. 341 the selector supervisory lamp is placed in series

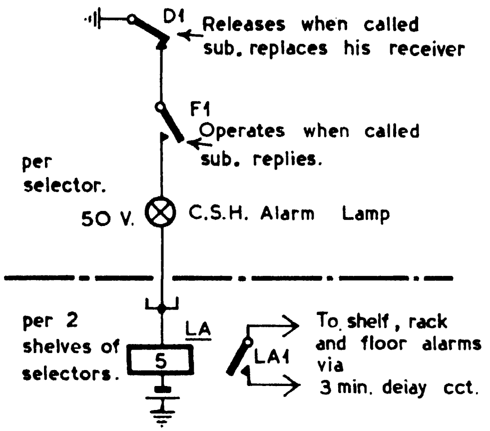


FIG. 342. CALLED-SUBSCRIBER-HELD ALARM CIRCUIT

with the alarm circuit. This has some disadvantages. In the first place the alarm is dependent upon the continuity of the lamp filament, and fails if the lamp filament becomes disconnected. Moreover, the electrical characteristics of small signal lamps vary appreciably from one lamp to another. Modern practice favours the segregation of the local selector lamp from the alarm circuit, so that the latter is independent of the characteristics and the life of the lamp. The alarm lamp is contained in a local circuit under the control of the *B* relay and the off-normal springs. These same contacts apply earth through a suitable resistor to the common alarm circuit.

Called-subscriber-held Conditions. It has been seen that (apart from certain special cases) the control of a call set up on an automatic switching system is vested in the calling subscriber. It is therefore possible for a calling subscriber to hold a switching train after conversation has terminated and the called subscriber has replaced his receiver. Under these conditions, the called subscriber's line is engaged for so long as the switches are held by the calling subscriber. This state of affairs is known as the *called-subscriber-held* (C.S.H.) condition, and, unless special measures are taken, an unscrupulous subscriber could take advantage of a business rival by falsely engaging the second party's line and thereby preventing the establishment of either incoming or outgoing calls.

In order to prevent the irregular holding of a called subscriber's line, all automatic switching circuits are arranged to give an audible and visual indication to the exchange maintenance staff if a called-subscriber-held condition is maintained for a period in excess of 3–6 min. Fig. 342 shows the principle of the C.S.H. supervisory arrangements of a final selector. *F*1 is a contact of the ring-trip relay and closes when the called subscriber replies. Almost immediately, relay *D* operates to the called subscriber's loop and *D*1 disconnects the C.S.H. supervisory circuit. At the end of the conversational period, relay *D* releases, but relay *F* is held operated until the selector is released. A circuit is therefore provided from the earth at *D*1 via *F*1 to light the selector C.S.H. alarm lamp. A low resistance supervisory relay (*LA*) is inserted in series with the battery supply to this circuit, and the contacts of *LA* in turn apply start conditions to a 3 min delay circuit. Details of this circuit are considered later, and for the moment it is sufficient to record that, if relay *LA* is energized continuously for a period of from 3 to 6 min, alarm lamps will light to indicate the rack and the section of the exchange concerned. By this means it is possible for the maintenance staff to locate the switch concerned and forcibly to release the connexion. It will be observed that, although the rack and section alarm lamps do not light until after the delay period of 6 min, the C.S.H. lamp on the selector itself glows from the time the called subscriber replaces his receiver until the circuit is released.

Release Alarm. The current in the rotary magnet of a 2000 type selector during rotary drive is in the order of 1 A. If this current were allowed to persist, there is a danger that it would burn out the magnet or, in extreme circumstances, might produce a risk of fire. It is necessary to guard against this contingency by providing a circuit which will give an alarm after a suitable period of delay if, for any reason, the rotary magnet were continuously energized. Such conditions could occur as a result of the welding of the rotary interrupter contacts or of a mechanical defect which produced jamming of the wipers.

Fig. 343 shows the release alarm circuit fitted

to all 2-motion selectors of the 2000 type. In order to prevent the operation of the release alarm during the normal rotary hunting in search of a free outlet, the arrangements are such that the supervisory relay is excluded from this circuit. Similarly, the release alarm must not operate during the rotary hunting of a normal release action. The supervisory relay must be included in the release circuit, but a 9 sec delay feature prevents false alarms on normal release.

In a group selector circuit, the rotary drive is completed by the release of relay *C* at the end of the vertical impulse train. The rotary magnet is now energized from the earth at ***H*1** via *R*1 and ***N*1** until such time as relay *H* releases when a free outlet is found. During this time the release alarm circuit is disconnected at contacts ***B*1** and ***H*1**.

When switching has been completed, relay *B* releases and prepares the rotary release circuit in readiness for the restoration of the *C* relay at the end of the call. At this time, the restoration of *C*1 completes the rotary drive circuit via ***N*1**, *R*1 and *B*1 to the earth at the 0·25 Ω release alarm relay (*RA*). Ordinarily, the *RA* relay is energized only for a fraction of a second, i.e. until the wiper carriage restores to normal, but, if a fault exists and the *R* magnet is permanently energized, the continuous operation of relay *RA* brings in shelf, rack, section, and floor alarms at the end of a 9 sec delay period. Test jack springs are invariably inserted in the release magnet circuit, but are normally looped by the insertion of a link. The release circuit of the selector can be disconnected at any time for maintenance by the removal of this link.

Clock and Ringing Machine Pulses. Current pulses of various frequencies are required for a wide variety of purposes in an automatic exchange. The two main sources of these pulses are an electric pendulum clock and the exchange ringing machine. The standard pulses available in most exchanges are:

Flicker Earth. This is an earth applied for 0·2 sec, with 0·2 sec between pulses. It is derived from a special cam on the ringing machine and is required on certain manual board relay sets, on chargeable time indicator equipment, on certain selectors in a director exchange, and so on.

Interrupted Earth. This is an earth pulse of 0·75 sec, with 0·75 sec between pulses. It is used on a wide variety of relay sets, director equipment, automatic routiners, and particularly on the relay sets which provide delayed alarm conditions.

1 *Sec Earth Supply.* This is a short pulse of current once every second and is derived from the electric clock. It is used for the alarm delay relay sets, for the graduated howler (q.v.) for certain traffic meters, and a number of other miscellaneous purposes.

6 *Sec Earth Supply.* This is a short pulse of current once every 6 sec, and is also derived from the electric clock. It has a number of miscellaneous uses (e.g. on C.T.I. equipment, etc.).

30 *Sec Earth Supply.* This is a short pulse of current once every 30 sec, and also comes from the electric clock. It is used particularly for the alarm delay circuits, but is also useful for a number of miscellaneous purposes.

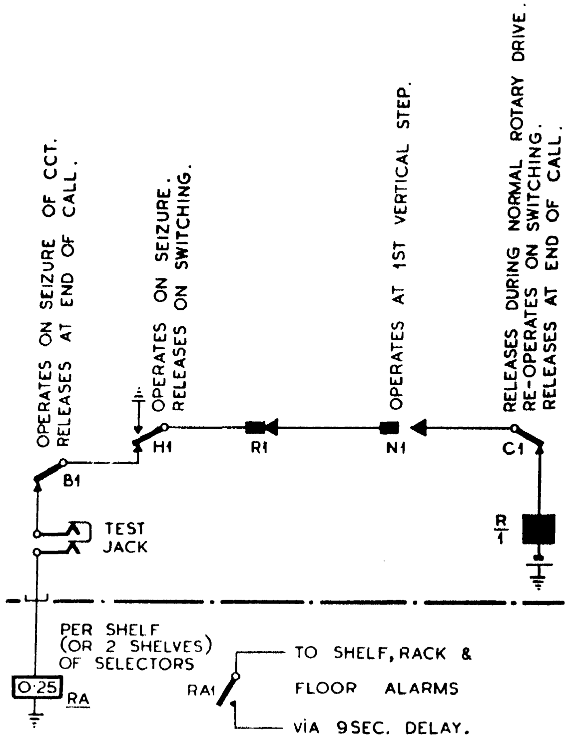


FIG. 343. RELEASE ALARM CIRCUIT (2000 TYPE SELECTOR)

The above basic pulses are utilized to provide a number of derived pulse systems to meet special requirements. For example, the 1 sec earth pulse from the electric clock is passed through a special halving circuit to provide a 2 sec pulse for use on certain routiners. The 6 and 30 sec earth pulses are similarly utilized to provide a system of specially phased *S* and *Z* pulses for use in the forcible release of certain items of equipment.

The various pulses are wired from the clock or ringing machine to a main "supply" jack on the A.E.R. From this point the pulses are passed through distribution jacks and then to the various

equipment racks as required. The supply jack and the distribution jacks are of the break type to facilitate the location of any fault on the common pulse supply system.

Pulses by Interacting Relays. In some circumstances it is inconvenient to obtain clock or ringing

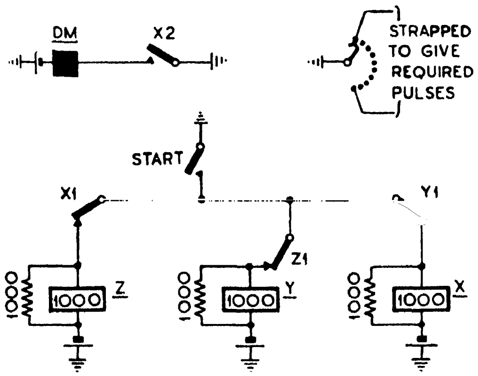


FIG. 344. METHOD OF GENERATING PULSES BY MEANS OF THREE INTERACTING RELAYS

machine pulses, and in such cases it is usual to employ a system of interacting relays to produce the basic pulses required. Interacting relays are suitable only for rough timing and should not be used where very accurate time intervals are required.

Fig. 344 shows a common type of interacting relay circuit which is capable of producing pulses down to a speed of approximately 1 pulse per second.

There are three relays in the circuit designated *X*, *Y*, and *Z*. Each relay is made slow-to-release, either by the provision of a slug or by a non-inductive resistance across the winding as shown. When the start contact is operated, all three relays are energized and contacts **X1**, **Y1**, and **Z1** disconnect the operate circuits. The relays now commence to release but, due to slight differences in the mechanical adjustments, one of the relays restores before the remaining two. Let it be assumed that this relay is *X*. The restoration of *X*1 re-establishes the circuit for relay *Z*, and **Z1** in turn breaks the circuit of relay *Y*. Slightly later, when *Y*1 returns to normal, a circuit is completed for the re-operation of relay *X*. In a short time, a regular periodical cycle is established in which the *X*, *Y*, and *Z* relays are operated in sequence.

The total time for each cycle of operations is determined by the sum of the operate and release lags of all three relays. When all the relays are of similar construction, and the pulse is taken from a make contact of one of the relays, then the period of the pulse is approximately one-third of the total timing cycle. If two contacts are used in combination, then it is possible to obtain a greater make ratio.

Contact **X2** can be used to step a uniselector or similar mechanism, the banks of which can be strapped to meet various timing requirements. The circuit is perfectly stable, but the time of the operating cycle is liable to vary after a period of use, due to changes in the operate and release characteristics of the relays.

Pulse Halving Circuits. Some circuits require an earth pulse supply which has a repetition rate not readily obtainable from the standard electric clock or the ringing machine. The requirements can often be met by selecting a pulse source of double the required frequency, and by inserting a pulse halving circuit between the pulse supply and the equipment.

Fig. 345 shows how it is possible to obtain an earth pulse once every 2 sec from an electric clock which gives a 1 sec pulse supply. The first earth pulse operates relay *PA*, and **PA1** applies earth to one coil of the *PB* relay. The latter does not, however, operate at this stage due to the

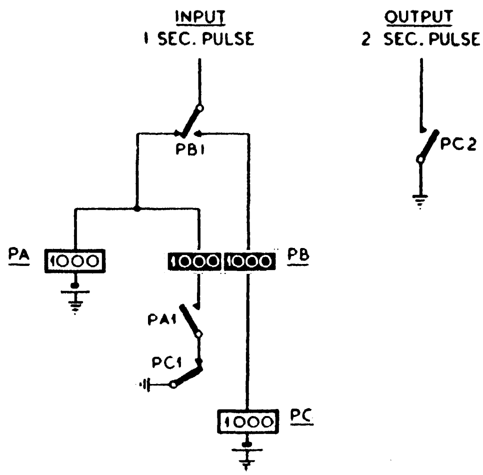


FIG. 345. METHOD OF OBTAINING A 2-SEC PULSE FROM A 1-SEC PULSE SUPPLY

earth on the other side of the coil from the clock pulse. At the end of the pulse, the removal of this earth permits relay *PB* to operate in series with *PA*, the latter being held over the same circuit. **PB1** now diverts the pulse supply circuit to the other coil of relay *PB* in readiness for the next earth pulse. The application of this second pulse operates *PC*, and holds relay *PB* until the end of the pulse period. **PC1** disconnects *PA* and the

initial operate circuit of relay *PB* in readiness for the termination of the pulse, whilst ***PC*2** applies earth to the output circuit. At the end of this second pulse, the disconnexion of the earth at the pulse source allows relays *PB* and *PC* to release, the *PC*2 contact terminating the output pulse. This cycle of operations continues for so long as the pulse supply is required. In effect, every alternate pulse is absorbed by operating relay *PA* and relay *PB*.

Alarm Delay Circuits. Fig. 346 shows a common circuit element used for introducing a delay in the setting up of alarm conditions. An alarm condition on an individual selector (or a relay set) is made to operate a relay which is common to all selectors on one, or sometimes two, shelves. This relay works in conjunction with a pair of relays per rack, which are connected via an *S* and *Z* pulse scheme to a suitable alarm delay relay set common to the exchange. Fig. 346 indicates the circuit arrangements for a selector release alarm. The permanent loop, called sub. held, and other conditions, utilize circuits which are fundamentally similar. The main differences are in the resistance and connexions of the shelf relays and the period of delay introduced by the alarm delay relay set.

If a selector fails to restore, relay *RA* operates in series with the rotary magnet of the selector (see Fig. 343). ***RA*2** connects arc *DS*2 of the alarm delay circuit to one coil of relay *AR* which is common to the rack. If there are no other alarm conditions, the uniselector in the delay circuit is at rest and earth is extended from one of the home contacts (i.e. 1, 8, or 15) of *DS*2 to operate relay *AR*. ***AR*1** provides a hold circuit for *AR* over its second coil to the battery at the shelf lamp. ***AR*2** applies earth to the start lead of the alarm delay relay set to operate relay *ST* in the latter. ***ST*2** applies the *PS* relay to the interrupted earth supply (0·75 sec earth, 0·75 sec disconnected). At the first earth pulse, *PS* operates and at ***PS*1** applies relay *PSA* to the pulse lead. At the end of 0·75 sec the earth is removed, and *PSA* now operates in series with *PS*. ***PSA*1** switches over the inter-earth supply to the *PR* relay. The next earth pulse operates *PR*, and ***PR*1** completes a circuit for the slow-to-release relay *PM*. At the end of this second earth pulse, ***PR*1** releases, and a circuit is completed for the uniselector driving magnet (*DS*) during the release lag of *PM* (i.e. until *PM*1 restores). By this means the uniselector makes one step every 1·5 sec.

After six steps the *DS*3 wiper applies earth to the *Z*-lead to operate relay *BR* on the selector rack. ***BR*1** provides a holding circuit for the *BR* relay to the battery at the shelf lamp, and at the same time shunts the holding circuit of relay *AR*. ***BR*3** applies earth to the main alarm system to energize the section and floor lamps and the associated alarm bells, whilst ***BR*4** lights the rack lamp. The alarm condition now remains until the *BR*

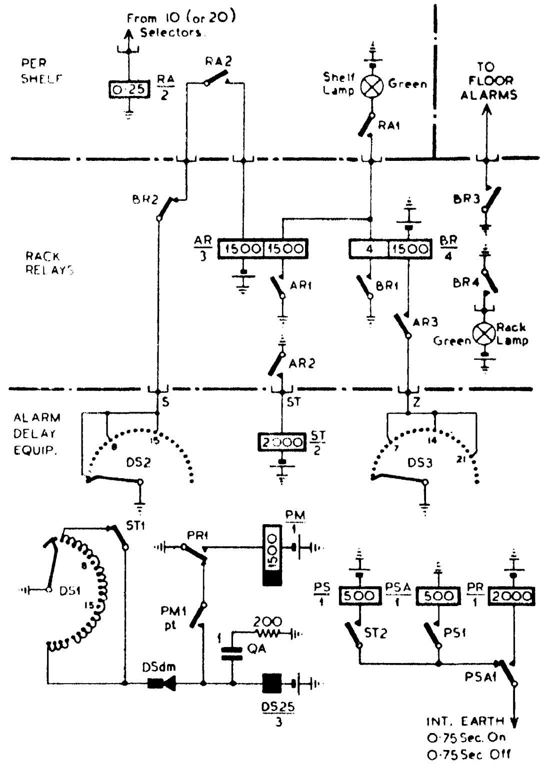


FIG. 346. TYPICAL ALARM DELAY CIRCUIT (RELEASE ALARM)

relay is released by the removal of the fault condition (i.e. by the release of *RA*1).

The release of relay *AR* consequent upon the receipt of the *Z* pulse removes the start condition from the common alarm delay relay set. The uniselector now rotates under self-drive until it reaches the next home position.

It will be noted that, if a second alarm condition occurs during the timing period of an earlier alarm, the second circuit must wait until the uniselector reaches a home contact before the timing cycle can commence. This means that, in the case of a nominal 9 sec delay period, the actual delay may vary from a minimum of 9 sec up to a maximum time of approximately twice this amount.

The alarm delay relay set circuit is the same for

all conditions, but the shelf jacks are strapped to give the required delay interval. Interrupted earth is used for stepping the uniselector for the 9 sec release alarm delay period. A 30 sec clock pulse is used for the alarm delay sets which are required to give the 3 min delay period for called sub. held, and the 6 min delay period for permanent loop conditions. The arrangement of the *PS* and *PSA* relays ensures that stepping always commences at the beginning of a pulse period. This is not of great importance on the 9 sec delay sets, but the absence of this feature could produce irregular timing when the uniselector is stepped by 30 sec earth pulses.

Other Delay Circuits. Although the uniselector type of alarm delay circuit described in the previous

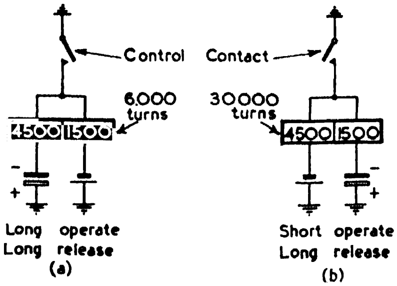


FIG. 347. METHOD OF OBTAINING DELAY FEATURE BY USE OF ELECTROLYTIC CAPACITOR

circuit is the usual method of obtaining the various delay periods required for alarms and other purposes, there are numerous other methods of providing alarm delay conditions. One alternative method (which was used to a considerable extent in the earlier automatic exchanges) is to provide a special relay with a ratchet and pawl system under the control of two coils. One electromagnet is arranged to step the ratchet wheel in response to clock pulses only when the second electromagnet is operated under alarm conditions. Suitable contacts on the relay close after the predetermined delay period.

Shorter delay periods can be obtained by the use of oil dashpot relays. Such relays were in fact used for a considerable time for the release alarm on selector racks. Thermal delay relays of various types have also been used in various capacities to provide suitable long delay periods.

Fig. 347 is an interesting delay circuit utilizing an electrolytic capacitor to provide long operate and release lags. The relay is of normal construction and has two coils of 4500 and 1500 Ω with a turn ratio of 5 : 1 respectively. A low-voltage, high-capacity electrolytic capacitor is connected to one winding, whilst battery is applied to the second winding of the relay. With the relay unoperated, full battery voltage is applied to the electrolytic capacitor so that the latter is fully charged when the circuit is idle. This prevents deterioration with time.

In diagram (*a*), the closure of the control contact applies earth to both coils of the relay. The electrolytic capacitor now discharges through the 4500 Ω winding, whilst the current rises (in accordance with Helmholtz's law) in the 1500 Ω winding. The magnetic effects of these two coils are opposite in direction, whilst the resistance and turns are so adjusted that, at the commencement of operation, the 4500 Ω winding predominates, but the effective flux is not sufficient to operate the relay. As the discharge current dies down, the net flux falls to zero and then grows in the opposite direction as the current rises in the 1500 Ω winding. The relay therefore operates after an appreciable time delay, which is largely determined by the value of the capacitor.

When the control contact opens to release the relay, the capacitor commences to charge through both windings in series. This charging current holds the relay until such time as the flux falls below the release value. A 20 sec operate lag can readily be obtained with a 1400 μF capacitor. Alternatively, a 50 μF capacitor will give a lag of the order of 1 sec. The release lag is approximately one-half the operate lag in each case.

Diagram (*b*) shows how the same relay can be made to give a short operate but a long release lag by reversing the positions of the two coils. On operation, the opposing flux of the capacitor discharge is much smaller due to the smaller number of turns on the 1500 Ω winding. At the same time, the effect of the direct current in the 4500 Ω winding is much greater than before. By this re-arrangement the operate lag can be reduced to about one-sixteenth for the same value of release lag.

Fuse Alarm Circuit. The power distribution to automatic exchange circuits is taken through alarm type fuses usually mounted on the equipment rack itself. Alarm type fuses are available in various sizes, the more important being the yellow, red, and black bead types which have current ratings of 1·0 A, 1·5 A, and 3·0 A respectively. In some cases it is necessary to provide one fuse per selector or relay set, but in other circumstances it is possible to arrange for one fuse to supply battery to a complete shelf of 10 selectors or relay sets. Generally speaking, circuits which supply the transmitter current to the calling and called subscribers require an individual fuse per

circuit. Other circuits, such as group selectors (which require comparatively little current during the conversational period) can be served on the basis of 1 fuse per 10 selectors.

The standard alarm type fuse has been described in Vol. I, and is used in conjunction with a fuse alarm circuit so arranged that, when a fuse blows, immediate (or prompt) alarm conditions are established. Fig. 348 shows a typical fuse alarm circuit. The individual fuses are placed in the mounting in such a way that, when the fuse blows, the main battery busbar is connected to the alarm bar of the fuse mounting. It is, of course, of the utmost importance that a fuse should not be reversed in its mounting, and to prevent such an occurrence, most of the standard mountings are designed so that such an error is physically impossible. The alarm bars of the fuse mountings are connected to a red alarm lamp which is common to the rack. The other side of the lamp is connected to earth via a fuse alarm relay (*FA*) which is common to one subsection of the exchange. If any fuse on the rack blows, the alarm tongue of the fuse connects the main battery busbar to the alarm bar, and thereby completes a circuit for the operation of relay *FA* and for the lighting of the rack lamp. Contacts of relay *FA* are arranged to operate the main visual and audible alarm system of the exchange.

The wiring of the fuse alarm circuit must also be protected against an accidental short circuit which might possibly incur a risk of fire. This protection is provided by a separate alarm type fuse. The failure of this fuse would cut off the main fuse alarm system of the rack, and hence it is desirable that the blowing of this fuse should initiate prompt alarm conditions. The alarm bar of this individual fuse is connected to a second coil of the subsection *FA* relay. Failure of the alarm circuit fuse therefore causes the *FA* relay to operate over both coils in series.

Forced Release. In certain circumstances it is important that the common switching equipment of an automatic telephone exchange should not be held for an abnormally long period due to fault conditions or subscribers' mis-operation. Such conditions occur in small Unit Automatic Exchanges where the total number of connecting circuits is comparatively small. If these connecting circuits were seized but not used by a calling subscriber or by a faulty subscriber's line, then there is a danger of a serious degradation in the grade of service. In other cases certain common apparatus is required only during the setting up of a call, and the comparatively short holding time makes it possible to meet the service requirements by a small number of circuits. Here again safeguards must be taken to prevent the common equipment from being held for a prolonged period due to fault or other conditions.

False congestion due to abnormal holding times can be avoided by providing a means of forcibly releasing the equipment at the expiration of any predetermined time. Fig. 349 shows a typical circuit element used to provide forced release conditions on a 2-motion selector. Any such circuit requires that there shall be a predetermined minimum period between the seizure of the circuit and the application of forcible release. This minimum period must be independent of the actual time (relative to the time pulse system) when the circuit is seized.

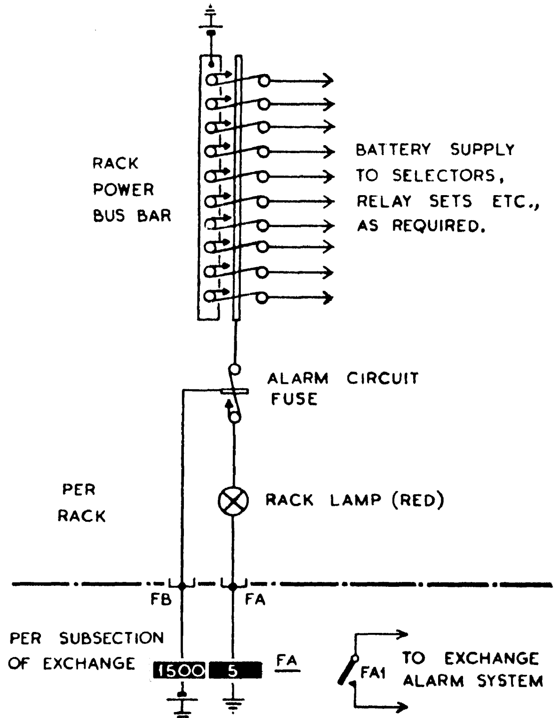


FIG. 348. ARRANGEMENTS OF FUSE ALARM CIRCUIT

In Fig. 349 it is assumed that relay *C* operates by the closure of contact **A1** when the selector is seized by a caller. For purposes of illustration let us assume that forced release conditions are to be applied if the selector is not stepped after the expiration of 30 sec from the time of seizure. Contact **C1** extends one coil of the *TP* relay to the common *S*-lead. Relay *SO* is operated for a short period every 30 sec by means of pulses from

an electric clock. *SO*1 energizes the slugged relay *ZO*. At the end of the clock pulse *SO* releases and, during the release lag of *ZO*, applies earth to the common *S*-lead. If the **C1** contact is closed at this time, relay *TP* operates and locks on its second

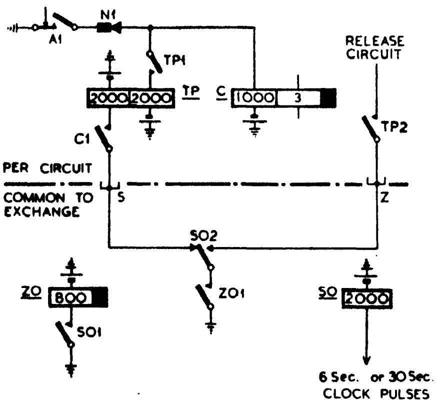


FIG. 349. FORCED RELEASE CIRCUIT

coil to the *A*1 earth. If the circuit is stepped during the ensuing 30 sec period, the *N*1 contacts open and release relay *TP*. *TP* is also released if the circuit is released by the caller during this period (i.e. if *A*1 restores). If, however, the circuit is still held but has not been stepped at the end of the 30 sec period, the next operation of *SO* and *ZO* applies earth via the common *Z*-lead to the release circuit of the selector. The exact method of releasing the selector depends upon the detailed circuit arrangements.

It will be noted that, if the circuit is seized immediately after one of the clock pulses, the *TP* relay will operate 30 sec later, and the forced release condition will be applied after a further period of 30 sec, i.e. forced release takes place after a total period of 60 sec from the time of seizure. If, on the other hand, the circuit is seized just prior to one of the pulses, then forced release conditions will be applied in just over 30 sec from the time of seizure. The delay period before forced release conditions are applied can be adjusted to meet any requirements by the use of appropriate clock pulses. For example, the use of a 6 sec clock pulse will provide forced release in from 6 to 12 sec.

It is clearly of no value to release an important piece of common equipment if the fault condition merely causes the seizure of another circuit which must in turn be forcibly released in due course. Facilities must therefore be provided so that the calling circuit (or line) is prevented from seizing a second selector after it has once been forcibly released.

Traffic Meter Circuits. It has been explained in Chapter II that meters are provided in every automatic exchange so that the grade of service can be kept under continual review.

Fig. 350 shows the method of connecting *overflow* meters to the banks of group, etc., selectors. Such meters are usually provided on the basis of one per grading for each level of the selector. The meter is connected to the 11th step *P* bank contacts of the group concerned, and the selector circuit is so arranged that, when the wipers step to the 11th rotary position, an earth is applied to the *P* wiper to operate the meter. In Fig. 350 the earth is applied by the 11th step cam springs (**S1**), but in some circuits the earth is applied by other means. Whilst the main use of overflow meters is on group selector levels, such meters are also connected to the 11th rotary step of the last level of each P.B.X. group on over-10 P.B.X. final selectors and certain other selectors, such as A-digit selectors and discriminating selectors.

Circuits substantially similar to Fig. 350 are also used for such purposes as call counting meters (C.C.M.) in order that a record can be kept of the total number of calls handled by a particular piece of apparatus or on a given route. In such cases the meter is connected to a relay contact which operates once per call.

It is not possible to employ overflow meters at switching stages where continuously hunting mechanisms are employed (e.g. subscribers' uniselectors). In these circumstances it is usual to measure the number of calls which are passed over the last contact of the selector bank, and also the

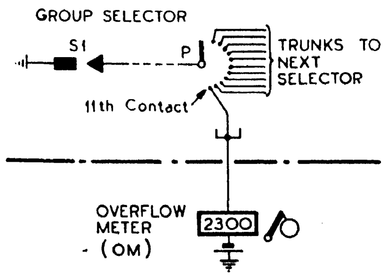


FIG. 350. CONNEXIONS OF OVERFLOW METERS

total duration for which this contact is engaged during a given period. The number of calls routed via the last contact is recorded on a *late-choice call meter* (L.C.C.M.), whilst the volume of traffic is measured by an associated time controlled meter known as the *late-choice unit meter* (L.C.U.M.).

Fig. 351 shows how the late-choice call meter is connected to a uniselector grading. One L.C.C.

meter is provided per grading and is commoned to the last working contacts of the P bank. When a subscriber lifts his receiver, he operates the L relay and, when the uniselector switches to a disengaged outlet, the **$L1$** contact extends a temporary earth forward for guarding purposes. When the last outlet is seized, this earth operates the L.C.C. meter. As the call is switched stage by stage to the final selector, the earth on the P-wire is maintained by the different switching stages until (in a non-director system) the earth is applied to the P-wire by a B relay contact in the final selector. Thus an earth is maintained on the P-wire from the moment the circuit is seized until such time as the earth is removed from the P-wire at release. The L.C.C. meter has a pair of contacts (***LCCM*1**) which apply the late-choice unit meter to a 30 sec earth pulse. Hence, whilst the late-choice call meter registers one unit for each call on the last trunk, the late-choice unit meter registers one unit for each 30 sec of time for which the last trunk is engaged. The readings of the L.C.U. meter can readily be converted into traffic units as described in Chapter II.

The circuit shown in Fig. 351 is liable to produce false readings if it is connected to a switching

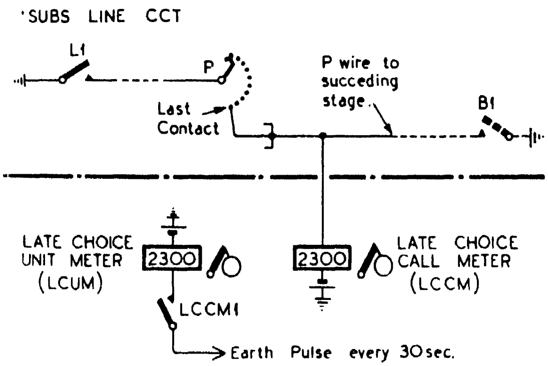


FIG. 351. CONNEXIONS OF LATE-CHOICE CALL AND UNIT METERS

train which provides for a guarded release of the selectors. Fig. 352 shows a modified circuit for use in such circumstances. As explained above, the earth is applied to the P-wire initially by the line relay contact of the subscriber's uniselector circuit, and is later maintained by the earth applied from the final selector (contacts **$C1$** of the intermediate group selectors being operated throughout the call). At the end of the call the earth is removed from the P-wire when $B1$ releases, but $B1$ in turn allows the switching relay of each group selector to release, and this releases the C relay. There is therefore an interval during the release

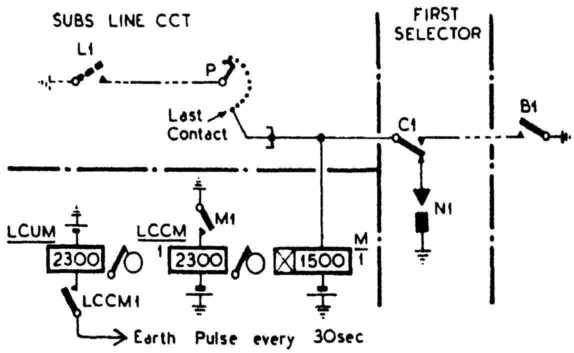


FIG. 352. ALTERNATIVE ARRANGEMENT TO PREVENT FALSE READINGS WHEN SELECTORS ARE PROVIDED WITH GUARDED RELEASE

of relays H and C when the earth is removed from the P-wire to allow the selectors to release. After this period, the earth is re-applied by off-normal springs (**$N1$**) to guard the selector against re-seizure until it has fully restored to normal.

If the circuit of Fig. 351 were used in these circumstances, the L.C.C. meter would operate due to the normal earth on the P-wire, and would release the moment that the $B1$ contact restored The re-application of the earth at the **$N1$** contacts of the 1st selectors would re-operate the meter until such time as the wiper carriage of that selector restored to normal. Thus there would be two registrations on the L.C.C. meter for one call. In order to prevent such false registrations, it is usual to interpose relay M between the P-wire and the L.C.C. meter (Fig. 352). The M relay is slugged and has a sufficiently long release lag to remain held during the short period when the earth on the P-wire is interrupted (i.e. during the release lag of relays H and C). The **$M1$** contact operates the L.C.C. meter, and ***LCCM*1** in turn provides a circuit for the L.C.U. meter.

Whilst the main use of L.C.C. and L.C.U. meters is on subscriber's uniselector gradings, they are also used in other circumstances where uniselector type mechanisms are employed.

EXERCISES X

1. Describe how the various tones are applied to the speaking conductors in an automatic exchange of the 2000 type. In what ways does this method of applying the tones differ from that used on earlier systems? What are the advantages of the scheme used on 2000 type circuits?

2. Give a diagram of the circuit elements concerned with the return of busy tone when a final selector is stepped to an engaged line.

3. What factors are concerned in the design of the windings, slug and spring sets for the ringing-trip relay which is required to remain unoperated while the bell is being rung, but to disconnect the ringing current when the called subscriber answers? Draw a diagram to show the complete circuit of the currents which flow through the line winding of the relay, and explain how the relay fulfils the required conditions. (*C. & G. Telephony, Grade III*, 1946.)

4. Describe, with the aid of a diagram, a method of producing the number unobtainable tone at an automatic exchange.

Give diagrams showing how the number unobtainable tone is connected:

(*a*) to selector levels, and

(*b*) to subscribers' lines.

(*C. & G. Telephony, Grade I*, 1941.)

5. Describe what provision is made in an automatic exchange to prevent the irregular holding of 1st selectors due to fault conditions or due to a subscriber accidentally removing his receiver. What alternative methods can be used to give an alarm when 1st selectors are irregularly held?

6. What is the purpose of the "called-subscriber-held" alarm? Describe how the alarm condition is established and the action which should be taken on receipt of such an alarm.

7. At a certain exchange a continuous supply of regular earth pulses at $\frac{1}{2}$ sec intervals is required. No suitable clock or ringing machine pulses are available. Describe two methods of obtaining the required pulse supply by the use of relays.

8. Give a diagram of the alarm delay circuit arrangements at a modern automatic exchange. For purposes of illustration it may be assumed that a 3 min delay circuit is required for the called-subscriber-held condition.

9. It is desired to provide a facility on a 1st selector whereby, if the subscriber seizes the selector but does not step it within a period of 1 min, the selector will be forcibly released from the calling line. Suggest suitable circuit arrangements in the subscriber's line circuit and in the 1st selector circuit.

10. Show how the grade of service in an automatic exchange can be kept under observation by the provision of suitable meters connected to the banks of group and other selectors. Illustrate with circuit elements.

CHAPTER XI

TYPICAL SELECTOR CIRCUITS

The six preceding chapters have dealt with the various elements of automatic switching circuits on a purely functional basis. These elements are in practice associated as required to form complete selector circuits. It is convenient at this stage to examine the more common types of selector circuit and to show how the individual impulsing, testing, switching, etc., elements are co-ordinated into a practical circuit design.

The exact trunking arrangements of an automatic exchange depend upon the type of exchange, the volume of junction traffic, the location and type of automanual switchboard and so on, but a substantial part of all exchanges consists of:

(*a*) Subscribers' uniselectors or linefinders whereby a calling subscriber can obtain access to a common group of 1st selectors.

(*b*) 1st, 2nd, and sometimes 3rd group selectors for switching a call through to the required group of final selectors.

(*c*) Final selectors which give access direct to the required subscriber's line.

(*d*) Auto-to-auto relay sets on the outgoing junctions to nearby automatic exchanges.

It has been seen in earlier chapters that linefinders are economical only in exchanges with a fairly low calling rate, and, in future, linefinder systems will in general be restricted to Unit Automatic Exchanges. Linefinder circuits have therefore been omitted from this chapter but are described later in connexion with specific U.A.X. schemes. All group selectors are substantially the same whether they are employed as 1st selectors, as 2nd selectors, or as 3rd selectors, and, generally speaking, the same circuit is used irrespective of the position of the group selector in the switching train. There are, on the other hand, several different types of final selector to cater for the various requirements of Private Branch Exchanges, and ordinary lines.

In each case the facilities provided by the particular circuit have been given, and reference is also made to the previously considered circuit elements which are utilized in the circuit. Finally, a more or less detailed chronological description of each circuit has been included, even although this involves some repetition of descriptions already given in respect of the component elements.

Subscriber's Uniselector Circuit. Fig. 353 shows a subscriber's uniselector circuit for use in exchanges with positive battery metering. The uniselector has three sets of bank contacts to provide for the negative, positive, and P-wires together with a fourth "homing" arc. Two controlling relays (L and K) are provided, whilst the meter and its associated metal rectifier are accommodated on a separate apparatus rack.

Facilities. The circuit provides the following facilities:

(*a*) When the subscriber lifts his receiver the uniselector searches for and seizes the first free outlet to a group selector.

(*b*) The subscriber's line is guarded from intrusion on incoming calls by the placing of a busy condition on the P-wire of the final selector multiple.

(*c*) The outlet seized is guarded from intrusion by other hunting uniselectors until such time as an alternative guarding earth is returned from the seized selector.

(*d*) When a free outlet is found, the subscriber's line is switched through to the 1st selector and all bridging apparatus is removed from the negative and positive wires.

(*e*) The circuit of the subscriber's meter is prepared for registration of the call when at a later stage positive battery is applied on the P-wire from the final selector.

(*f*) If a free outlet is not immediately available, hunting continues until either the subscriber clears or a free outlet is found.

(*g*) The wipers are restored to the home position at the end of the call when earth is removed from the P-wire.

(*h*) The subscriber's line is guarded from intrusion during metering and whilst the wipers are homing from a previous call.

(*i*) When the line circuit is seized by a final selector (on incoming calls), the negative and positive wires are cleared of all bridging apparatus.

Circuit Elements. The subscriber's uniselector circuit incorporates the self-interrupted drive and earth testing circuit of Fig. 256 and the double-arc homing circuit illustrated in Fig. 294. Until a guarding earth is returned from the subsequent selector, a temporary holding condition is maintained by the slow release feature of relay L as shown in Fig. 287. The metering circuit is the standard arrangement for positive battery metering and has been previously considered in Fig. 317.

Circuit Description. When the subscriber lifts his receiver, relay *L* operates in series with the loop from the subscriber's instrument. ***L1*** prepares the uniselector stepping circuit, whilst ***L2*** completes the circuit for stepping the uniselector wipers off the home contacts. At the same time ***L2*** applies earth to the home contact of the homing arc to engage the line on the final selector multiple. It is interesting to note in passing that the *L* relay is usually adjusted so that contact *L*1 operates before contact *L*2. This precludes the possibility of premature operation of relay *K* during the initial operation of *L* and also the incorrect switching of relay *K* to a busy outlet should the subscriber clear whilst the uniselector is hunting.

The uniselector driving magnet is initially operated from the earth at ***L2*** via the home contact of the *P* bank, ***L1***, *K*5, and the *Ddm* contacts. When the armature is attracted, the interrupter springs (***Ddm***) disconnect the magnet circuit and, on the release of the armature, the wipers are stepped to the second contact (i.e. to the first working outlet). If this first outlet is engaged, a circuit is again completed for the driving magnet from the earth on the *P* bank contact. The ***dm*** springs again disconnect the magnet circuit and the wipers are stepped to the next outlet. This process continues for so long as earth is encountered by the *P* wiper. During hunting, relay *K* is short-circuited due to earth on one side from ***L2*** and on the other side from the *P* bank.

When a free outlet is found, the driving magnet cannot be further operated due to the absence of earth on the *P*-wire. Relay *K* now operates in series with the driving magnet battery, but the current is insufficient to operate the magnet. ***K1*** and ***K2*** remove the *L* relay and earth from the speaking pair. ***K3*** applies earth to busy the outlet seized, and ***K5*** prevents this earth from operating the driving magnet during the release lag of *L*. It follows that ***K5*** must break before ***K3*** makes. ***K4*** applies earth to the meter in readiness for the subsequent registration of the call. Relay *L* has a release lag of some 100 msec in order to maintain the earth on the *P*-wire until it is replaced by a similar earth from the succeeding stage. If the uniselector switches to an early choice outlet, the total energization time of relay *L* is comparatively short. This relay is therefore fitted with an armature-end slug so that it is substantially fully fluxed before hunting commences and hence has a sufficiently long release lag to provide an interim guard on switching.

After the setting-up of the call and when the called subscriber replies, a 50 V positive battery is returned on the *P*-wire to operate the meter via the rectifier *MRA* to the earth at ***K4***. The rectifier is connected in such a direction as to offer a low impedance to the metering current, but effectively prevents irregular operation of the meter to the negative battery at the driving magnet. It will be noted also that the rectifier is connected so that relay *K* cannot hold to earth via the meter.

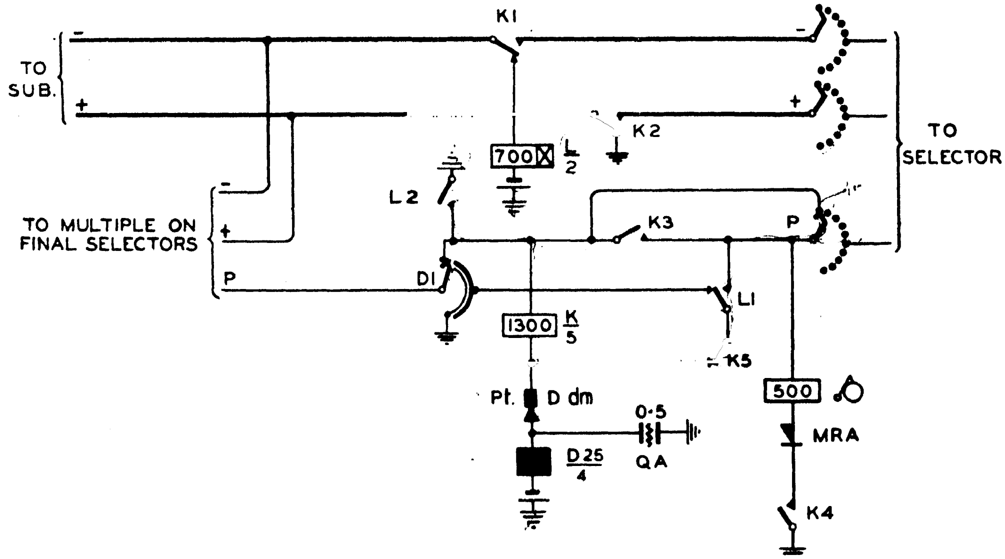


FIG. 353. SUBSCRIBER'S UNISELECTOR CIRCUIT
(Positive battery metering)

At the termination of the call, the removal of the earth from the *P*-wire releases relay *K* which at *K5* provides a self-drive homing circuit to the earth at the homing arc. The private-wire of the final selector multiple is engaged initially by the operation of contact *L2* and then by the earth on the homing arc itself until such time as the wipers

Relay *H*. Testing relay.

Facilities. The circuit provides the following facilities:

(*a*) When the selector is employed as a 1st selector in a non-director area, dial tone is returned to the calling subscriber immediately the selector is seized from the subscriber's uniselector circuit.

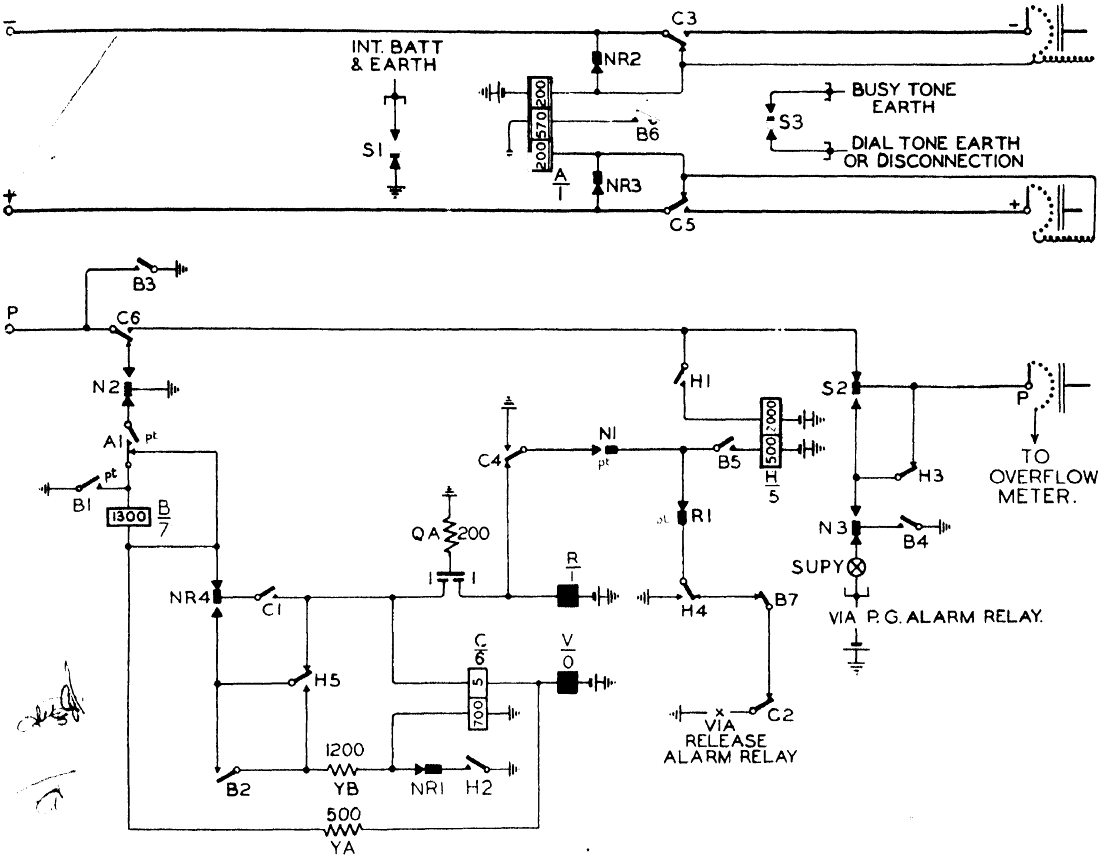


Fig. 354. 100-outlet Group Selector Circuit (2000 Type)

return to the normal position at the termination of a call.

On an incoming call, the application of earth to the *P*-wire by the final selector causes relay *K* to operate, which at *K1* and *K2* removes the bridging apparatus from the speaking pair.

100-outlet Group Selector. Fig. 354 shows the circuit of the group selector of the 2000 type with 10 outlets per level, i.e. a 100-outlet selector.

The four controlling relays have the following functions:

Relay *A*. Impulse and loop supervisory relay.

Relay *B*. Holding and guarding relay.

Relay *C*. End of impulse train signalling relay and, later, switching relay.

If the selector is used as a 2nd or subsequent selector, dial tone is omitted.

(*b*) Earth is applied to the *P*-wire when the selector is seized to guard the circuit against intrusion and to hold any preceding switches.

(*c*) The selector is stepped vertically under the control of impulses received from the calling subscriber's dial.

(*d*) The wipers are stepped automatically into the bank on the level chosen by the dialled impulses, and, if the first outlet is engaged, the wipers rotate to search for and seize the first free outlet in the level. When an outlet to a succeeding selector is seized, a temporary guarding earth is applied on the forward *P*-wire for a sufficient time

to enable a replacing earth to be returned by the selector seized.

(e) When an outlet is seized, the negative and positive lines are switched through and the speaking pair is cleared of all bridging apparatus.

(f) If all outlets in the level are engaged, the selector steps to the 11th rotary contact, operates an overflow meter and returns busy tone and flash to the caller.

(g) The selector releases when earth is removed from the *P*-wire at the final selector and guards itself against re-seizure during release.

(h) A supervisory alarm is provided should the switch fail to release due to a mechanical defect.

(i) A supervisory alarm is given after a delay period of some 6 minutes should the switch be seized but not stepped (first and incoming selectors only).

Circuit Elements. The following previously considered circuit elements will be recognized:

Impulsing circuit with pre-operated *C* relay and short-circuited *B* and *C* relays (Fig. 189).

Rotary drive circuit with pre-operated earth testing relay (Fig. 260).

Permanent loop alarm circuit (Fig. 340).

Release alarm circuit (Fig. 343).

Guarded release circuit (Fig. 297).

Dial and busy tone circuits (Figs. 329 and 331).

Overflow meter circuit (Fig. 350).

Circuit Description. Relay *A* operates to the subscriber's loop extended by the uniselector, and at ***A*1** operates relay *B* to the battery at the vertical magnet. ***B*1** provides an earth to the *B* relay and magnet circuits in readiness for impulsing. ***B*2** operates relay *C* with both coils and resistor *YB* in series to the vertical magnet battery. ***B*3** returns a guarding earth on the *P*-wire. ***B*4** completes the supervisory lamp and P.G. alarm circuit, if the circuit is used as a 1st or incoming selector. ***B*6** applies balanced dial tone (1st selectors only) via the inductive coupling of the *A* relay windings.

Relay *A* is released during each break impulse from the dial and at *A*1 repeats the impulses to the vertical magnet. At the first vertical step, the off-normal springs (*N*) operate. ***N*1** extends the earth from ***C*4** to energize relay *H*, whilst ***N*3** disconnects the P.G. alarm circuit. The *B* relay is held for the duration of each break impulse by the eddy currents resulting from the short circuit applied at *A*1, whilst the *C* relay is similarly held during the make period between impulses due to the short-circuiting of its 700 Ω winding by *NR*1 and ***H*2**.

At the end of the vertical impulse train, relay *C* releases. *C*4 completes the rotary magnet circuit via ***N*1** and *R*1 to the earth at ***H*4**. As the rotary armature is attracted, the wipers move into the bank, and in due course the ***R*1** springs operate to disconnect the rotary magnet circuit. After the release of relay *C*, the *H* relay is held to the earth at ***H*4** until such time as the ***R*1** springs operate. If the first outlet is engaged, an alternative holding circuit for relay *H* is now provided from the earth on the *P* wiper via contact ***H*1** and the 2000 Ω winding of *H*. As the rotary armature restores, the *R*1 contacts reclose, and the rotary magnet circuit is again established to step the wipers to the second bank contacts. The holding circuit of relay *H* is again dependent upon the condition on the *P* wiper during the period for which the ***R*1** contacts are open. If this second outlet is also engaged, the process continues until such time as a free outlet is found. The absence of earth on the first free outlet allows relay *H* to release during the operation of springs ***R*1**. *H*3 guards the outlet against seizure by other hunting selectors, whilst *H*5 re-operates relay *C* over both windings in series. ***C*3**, ***C*5**, and ***C*6** extend the negative, positive, and *P*-wires to the succeeding stage. ***C*4** re-operates *H*. Relays *A* and *B* now release, but relay *H* is held to the *P*-wire via ***H*1**, and relay *C* is held via ***H*5**, ***NR*4**, and ***C*1**.

If all outlets on the level are engaged, the wipers step to the 11th rotary position and the *S* springs operate. ***S*3** connects busy tone to the *A* relay, whilst ***S*2** operates the overflow meter and allows relay *H* to release. *H*5 re-operates *C*, and the contacts of *C* re-energize *H* and switch the −, +, and *P*-wires as on an effective call. ***S*1** connects busy flash to the positive wire via the *A* relay which now holds via the 11th step bank contacts.

At the termination of the call, relay *H* releases due to the removal of the earth from the *P*-wire. *H*5 releases *C* which at *C*4 completes the self-drive for the rotary magnet which now homes the switch. The earth is removed from the *P*-wire during the release of *H* and *C*, but is re-applied by *C*6 until the *N*2 springs restore when the switch is fully restored to normal, thereby guarding the switch against re-seizure during its release movement. If the wiper carriage fails to restore due to a mechanical defect, the prolonged energization of the *R* magnet brings in the release alarm circuit after a delay of some 9 seconds.

200-outlet Group Selector. It has been shown (Chapter II) that, when the volume of traffic is reasonably large, considerable economies can be effected by providing group selectors with an availability of 20 outlets per level. Such selectors are known as 200-outlet group selectors, and owing to their higher efficiency they have largely superseded the 100-outlet type selector except in

a few special cases where the volume of traffic is comparatively low. Fig. 355 shows a typical 200-outlet group selector circuit of the 2000 type. It is fundamentally similar to the 100-outlet circuit already considered but includes the dual testing circuit already described in Fig. 261. Apart from the additional testing relay and the doubling of the negative, positive, and P banks, the circuit features are comparable with the 100-outlet selector.

The facilities provided by the circuit are also similar apart from the arrangement for testing two outlets at each rotary step. A test jack is provided so that a maintenance officer can readily ascertain which of the two outlets on which the wipers are standing has been seized. The short-circuiting of the test jack springs is made to operate a rack bell when the lower set of wipers and bank contacts are in use.

Circuit Description. The selector is seized by a loop on the positive and negative lines from the preceding selector. Relay A operates to this loop and at **A1** operates relay B to the battery at the vertical magnet. The current is, of course, insufficient to operate the vertical magnet owing to the resistance of the B relay and the 500 Ω resistor in series. **B1** completes a holding circuit for relay B and provides an earth for the subsequent energization of the vertical magnet. **B2** operates relay C on its 700 Ω coil and lights the P.G. supervisory lamp. **B3** earths the P-wire to guard the selector against intrusion and, if necessary, to hold the preceding equipment. **B4** extends the earth from **B3** via *HB*7 and *S*2 to complete the P.G. alarm circuit. **B6** connects dial tone to the 570 Ω winding of relay A. The P.G. alarm, dial tone, and the selector supervisory lamp are provided only on 1st selectors.

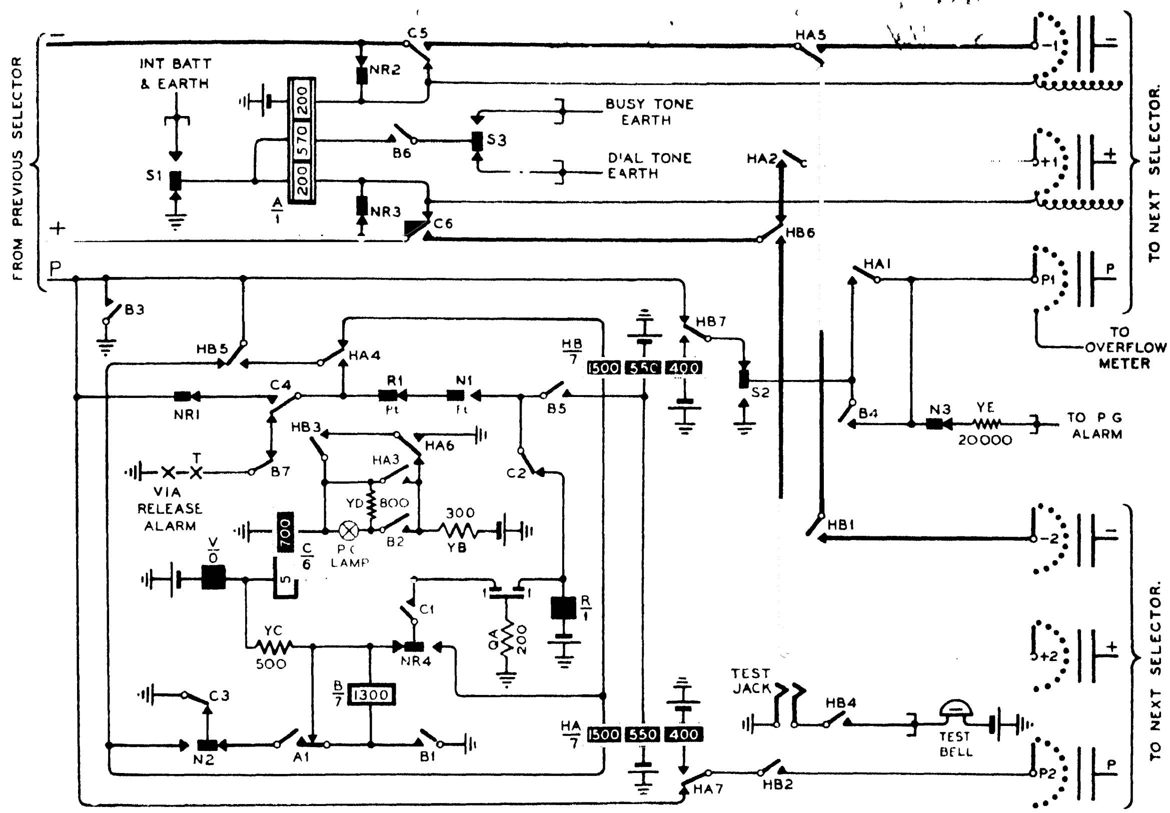


FIG. 355. 200-OUTLET GROUP SELECTOR CIRCUIT (2000 TYPE)

Relay A responds to the impulses received, and, at each release of A1, a pulse of current is applied to the vertical magnet from the earth at **B1**, the B relay being held during the impulse train due to the slugging effect of the short circuit across its winding. At the first vertical step, the off-normal springs operate. **N1** operates relays HA and HB on their 550 Ω coils, whilst **N3** disconnects the

P.G. alarm circuit. An alternative holding circuit is now provided for relays *HA* and *HB* by ***HB*5** and ***HA*4** via *R*1, ***N*1**, and ***B*5**. ***HA*6** and ***HB*3** short-circuit the pre-operate coil of relay *C*, thereby making the relay dependent upon the pulses of current in its 5 Ω winding. (The P.G. alarm lamp is also dimmed at this stage.) Relays *B* and *C* hold by virtue of their slow release features throughout the train of impulses, and, at the end of the vertical train, relay *C* releases but *B* remains operated to the earth at ***B*1**.

When the *C* relay restores, *C*1 disconnects the vertical magnet circuit to prevent any further pulses to the magnet, whilst *C*2 energizes the rotary magnet to the earth via ***N*1**, *R*1, ***HA*4**, ***HB*5**, and ***B*3**. The selector wipers are now stepped into the bank and the rotary off-normal springs operate. Contacts ***NR*2** and ***NR*3** place the *A* relay under the control of contacts *C*5 and *C*6 in readiness for switching to a free outlet. At a late point in the forward stroke of the rotary magnet armature, the rotary interrupter springs (***R*1**) operate and disconnect both the rotary magnet circuit and the holding circuits of relays *HA* and *HB*. The holding of the two testing relays is at this point dependent upon the conditions on the *P*1 and *P*2 wipers. If both outlets are free, relays *HA* and *HB* release. *HB*7 guards the *P*1 outlet and *HB*3 removes the short circuit from the 700 Ω coil of relay *C* and allows it to re-operate. **C1** in turn completes a re-operate circuit for *HA* from the battery at the vertical magnet via **C1**, ***NR*4**, 1500 Ω coil of *HA*, and *HB*5 to the earth at ***B*3**. **C2** cuts the rotary drive circuit, whilst **C5** and **C6** remove the *A* relay from the speaking pair and switch through the lines. Contact ***HA*1** provides a holding circuit for relay *HA* (when relay *B* releases) to the earth returned on the *P*1-wire from the next switching stage. Contacts ***HA*2** and ***HA*5** complete the switching of the positive and negative wires to the "odd"-numbered outlet. ***HA*3** provides a holding circuit for relay *C*.

If the *P*1 (odd) outlet is free but the *P*2 (even) outlet is engaged, relay *HB* releases due to the absence of earth at the *P*1 wiper. Relay *HA*, on the other hand, holds to the engaging earth on the *P*2 wiper. The release of *HB*2 now releases relay *HA*, whilst *HB*3 removes the short circuit from the 700 Ω coil of *C* and allows it to re-operate. *HB*5 prepares the re-operate circuit for relay *HA*. The circuit operation is then as described above.

If the alternative conditions exist, i.e. if the even outlet is free but the odd outlet is engaged, relay *HA* releases but relay *HB* holds to the earth on the *P*1-wire. Relay *HA*, in releasing, removes at *HA*6 the short circuit from the 700 Ω coil of relay *C* and allows it to re-operate whilst *HA*7 guards the *P*2 outlet. **C1**, in operating, completes a holding circuit for relay *HB* on its 1500 Ω coil. **C2** disconnects the rotary magnet circuit, whilst **C5** and **C6** extend the speaking pair as already described.

If both outlets are engaged, relays *HA* and *HB* are held (after the operation of the ***R*1** contacts) to the earth on the *P*2- and *P*1-wires respectively. The rotary magnet releases, and, when the *R*1 springs remake late in the return stroke of the armature, the magnet circuit is again completed and the wipers are stepped to the second outlet on the level. Rotary hunting now proceeds until a free outlet on either the *P*1 or *P*2 banks is encountered. If all outlets on the level are engaged, rotary stepping continues until the wipers reach the 11th rotary position. The *S* springs now operate. ***S*1** and ***S*3** transmit busy tone and flash to the calling party and provide a holding circuit for relay *A* on its 570 Ω coil during the busy flash period. ***S*2** applies earth to the *P*1 wiper to operate the overflow meter associated with that level. It will be noted that when the selector steps to the 11th position, the operation of ***S*2** causes the selector to switch to the odd outlet. Relay *A* is now held via the bank contacts of this outlet to prevent the selector from releasing when relay *C* re-operates on switching.

On completion of the call, the holding earth is removed from the *P*-wire of the outlet seized. Relay *HA* or relay *HB* (depending upon whether switching has taken place to the odd or the even outlet) now releases. Contacts *HA*2 and *HA*5 or *HB*1 and *HB*6 disconnect the speaking pair, whilst *HA*1 or *HB*2 disconnects the *P* wipers. Either *HA*3 or *HB*3 releases the *C* relay. *C*2 and *C*4 complete the drive circuit for the rotary magnet which causes the wipers to step to the 12th rotary position and then to restore vertically. *C*3 connects earth to the incoming *P*-wire to guard the selector during release, i.e. until contacts *N*2 restore. It will be seen that the total unguard period during release is equal to the combined release lags of relay *HA* (or relay *HB*) and relay *C*.

100-line Final Selector. Fig. 356 shows a simple form of final selector circuit designed to give access to 100 subscribers' lines. The circuit contains 9 relays which are used as follows:

Relay *A*. Impulse accepting relay and transmission bridge impedance element for calling subscriber.

Relay *B*. Holding and guarding relay.

Relay *C*. End of impulse train signalling relay.

Relay *D*. Called subscriber's supervisory relay and impedance element in transmission bridge to called subscriber.

Relay *E*. Vertical to rotary switching relay.
Relay *F*. Ring-trip relay.
Relay *G*. Busy relay.
Relay *H*. Testing and switching relay.
Relay *J*. Metering relay.

Facilities. The selector provides for the wiper carriage to be stepped vertically under the control of the first impulse train, and then to the required bank contact in the selected level by a second impulse train. If the called subscriber is engaged, the selector does not switch, but busy tone and busy flash are returned to the caller. This condition continues until the selector is released (irrespective of whether or not the selected line becomes free during that period). If the required line is disengaged, switching takes place and ringing current is applied to the negative wire to operate the magneto bell at the called telephone. At the same time, ringing tone is returned to the caller to indicate that switching has taken place to the called line.

When the called subscriber replies, the ringing current is disconnected and the called party is extended to the transmission bridge. The ringing tone is removed and conversation can now proceed. When the called subscriber answers, a short pulse of positive battery is returned on the *P*-wire to operate the meter in the calling subscriber's line circuit. If, at the end of the conversation, the called subscriber replaces his receiver but the selector is still held by the calling subscriber, called-subscriber-held conditions are established, and an alarm is given after a period of delay.

When the calling subscriber replaces his receiver, rotary drive conditions are set up until the wipers are clear of the bank, when the wiper carriage restores to the normal position. The usual release alarm is given if the wiper carriage fails to restore. Throughout the call the circuit provides the necessary conditions to hold previous selectors in the chain and the switching relay in the called subscriber's line circuit.

Circuit Elements. The complete final selector circuit illustrated in Fig. 356 is built up of the following elements already considered in earlier chapters:

Vertical and rotary stepping under control of dial (Fig. 191).
Busy circuit (Fig. 333).
Battery testing circuit (Fig. 262).
Ring-trip circuit (Fig. 336).
Transmission bridge circuit (Fig. 282).
Positive battery metering circuit (Fig. 317).
Called-subscriber-held circuit (Fig. 342).
Guarded release circuit (Fig. 298).

Circuit Description. Relay *A* operates from the calling subscriber's loop (extended from the previous selector) and at **A1** operates *B* to the battery at *YB*. **B1** completes the pre-operate circuit for relay *C*, whilst **B2** applies a holding and guarding earth to the incoming *P*-wire. **C1** prepares the vertical stepping circuit in readiness for the first break of contact *A*1.

Relay *A* releases at each break of the dial springs, and extends the earth from **B5**, through the *C* relay, to step the vertical magnet of the selector. The pre-operate coil of relay *C* is short-circuited by the closure of the **N2** contacts at the first vertical step, but the relay holds during the impulse train due to the pulses of current in its 5 Ω winding. At the end of the impulse train, relay *C* releases and at *C*2 completes a circuit for relay *E* to the battery at the vertical magnet. (The vertical magnet does not, of course, operate due to the high resistance of *E*.) **E3** removes the short-circuiting earth from the 700 Ω coil of the *C* relay to allow this relay to pre-operate in readiness for the second impulse train. The re-operation of **C1** again prepares the impulsing circuit, but this time the impulses are directed via **E2** to the rotary magnet of the selector. At the first rotary step, the changeover of the rotary off-normal contacts **NR2** again applies earth to short-circuit the 700 Ω coil of *C*, thereby making the holding of this relay again dependent upon the impulses in the 5 Ω coil.

At the end of the second impulse train, *C* releases as before and at *C*2 breaks the hold circuit of relay *E*. (During the rotary impulse train *E* holds via **C2** and the **E1** contact.) At the same time, *C*4 applies earth to the 900 Ω coil of the *H* relay, the other side of the coil being connected to the *P* wiper of the selector. If the called subscriber's line is engaged, the earth on the *P* bank contact prevents the operation of relay *H*. After a period of lag, the *E* relay restores and at *E*3 removes the short circuit from the 700 Ω coil of *C*, thereby allowing the latter to re-operate. **C4** disconnects the circuit of the testing relay. The restoration of *E*5 completes a circuit for the *G* relay (note that *H*3 is normal in this case). Contact **G1** now applies interrupted battery and earth to give a busy flash signal to the calling party. (This is required only when the call emanates from a manual switchboard.) At the same time, **G2** completes the circuit of the 570 Ω coil of relay *A* to give busy tone to the calling subscriber.

If the called line is disengaged when contact *C*4 releases at the end of rotary stepping, relay *H* operates to the battery at the *K* relay in the subscriber's line circuit (see Fig. 353).

The *E* relay releases some 300 msec after the

restoration of the *C* relay and, as before, contact *E*3 allows the *C* relay to re-operate by the removal of the earth from one side of its 700 Ω winding. A circuit is therefore prepared for the *E* relay by contact ***C*2** in readiness for the operation of relay *D*.

H*1** completes the local holding circuit of the *H* relay, whilst ***H*2** applies a guarding and holding current back towards the calling party to give supervisory conditions. ***D*1** now completes a circuit for the *E* relay, which operates. ***E*4** applies the positive battery metering potential to the incoming *P*-wire (E*6** removing the earth during the metering period). ***E*5** disconnects the circuit of relay *J*, and after a delay period due to the

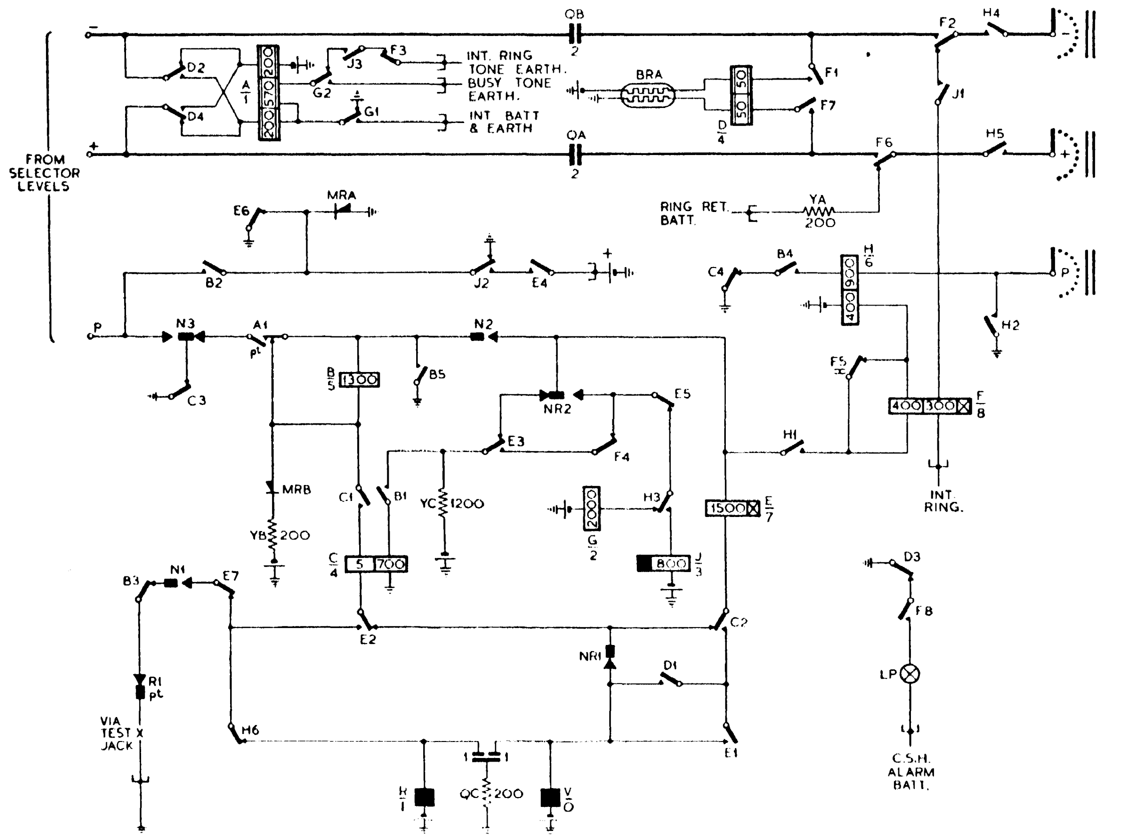


FIG. 356. 100-LINE FINAL SELECTOR CIRCUIT (2000 TYPE)

earth to the *P*-wire of the seized line. *H*3 completes a circuit for the operation of the *J* relay in readiness for metering at a subsequent stage. Contacts ***H*4**, ***H*5**, and ***J*1** connect interrupted ringing and the ringing return battery to the called line, and, at the same time, ***J*3** transmits ringing tone to the caller. In due course the called subscriber answers, and the completion of the d.c. loop allows the *F* relay to operate. ***F*5** removes the short circuit from the 400 Ω coil of *F*, thereby permitting the *F* relay to hold in series with the 400 Ω coil of *H*. ***F*1**, ***F*2**, ***F*6**, and ***F*7** extend the called party to the transmission bridge.

Relay *D* operates to the called subscriber's loop current and at ***D*2** and ***D*4** reverses the line release lag of *J*, the positive battery metering potential is removed by contact *J*2.

The call is now established for conversation. Relays *A* and *D* are held by the calling and called subscribers' loops respectively. Relay *B* provides a holding and guarding earth on the incoming *P*-wire, and at the same time holds relays *C*, *E*, and *H*. ***H*2** in turn provides the holding condition to the called subscriber's line. If the called subscriber is the first to replace his receiver, the restoration of *D*3 lights the selector supervisory lamp and extends earth to the C.S.H. alarm system. If this condition persists for the delay period, the selector must be released by hand.

When the calling subscriber replaces his receiver,

relays A, B, C, E, and H release. A circuit is now completed for the rotary magnet via the $R1$ contacts to the release alarm earth. The wipers are therefore stepped round to the 12th rotary position under self-interrupted drive, and the wiper carriage then falls to normal. The opening of the off-normal springs ($N1$) disconnects the rotary magnet circuit. During the period between the release of the $B2$ contacts and the restoration of the $C3$ contact, the earth is removed from the incoming P-wire to allow all preceding selectors to restore. At the end of this period, earth is re-applied at $C3$ until such time as the $N3$ contacts restore, i.e. when the selector shaft is normal.

200-line Final Selector. It was shown in Chapter II that economies can be made in the switching plant costs by the use of final selectors which will give access to 200 lines. The 100-line final selector is now very rarely used in modern exchange design and in all but special circumstances 200-outlet selectors are universally specified. Fig. 357 shows a typical 200-line final selector designed for giving access to ordinary (i.e. *not* P.B.X.) lines.

Facilities. In addition to the facilities already enumerated for the 100-line final selector, the 200-outlet circuit is arranged so that on receipt of a discriminating signal from the preceding group selector, the circuit is switched either to the odd or to the even set of wipers as required. Discrimination is effected by the addition of a wiper-switching relay (WS) in the positive line of the even outlet from the preceding switch. Thus, if the final selector is seized from the even outlet, the wiper-switching relay is energized and prepares the circuit for the switching of the call to the appropriate wipers. A test bell is provided to enable maintenance staff to determine whether the odd or the even outlet is in use, without the necessity of removing the relay cover to examine the condition of the switching relay.

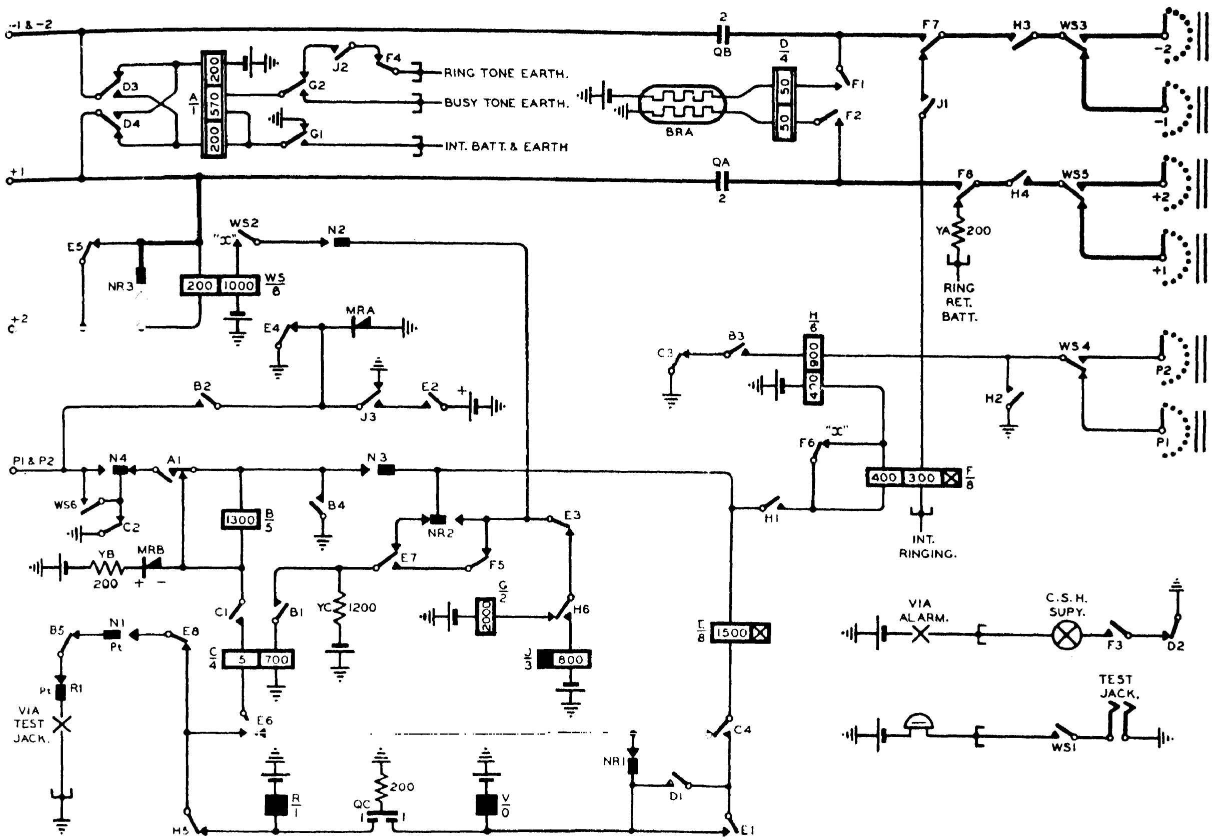


FIG. 357. 200-LINE FINAL SELECTOR CIRCUIT (2000 TYPE)

The complete circuit shown in Fig. 357 is built up of the same elements as the 100-line selector

with the addition of the wiper-switching circuit illustrated in Fig. 281.

Circuit Description. Relay *A* operates from the subscriber's loop extended from the previous selector and at **A1** operates relay *B* to the battery at resistor *YB*. **B1** completes the circuit for relay *C* to the battery at *YC*. **B2** provides a guarding and holding earth on the *P*-wire, whilst **B4** applies a common earth for holding relay *B*, etc. At the first vertical step, the off-normal springs **N3** operate, and the 700 Ω pre-operate winding of *C* is short-circuited by the earth from **B4**. Relay *C* holds during reception of the impulse train but, during the inter-train pause, *C* releases and at *C*4 provides an operate circuit for the *E* relay from the earth at **B4** via **N3**, *E* relay, *C*4, *NR*1 to the battery at the vertical magnet. **E7** allows *C* to re-operate, and relay *E* now holds via contact **E1** independently of the *NR* springs. **E5** removes the short circuit from the 200 Ω winding of relay *WS* and allows this relay to operate if the call originates over the − 2 and + 2 wires from the preceding selector. **E6** changes over the impulsing circuit from the vertical to the rotary magnet.

The units train of impulses is routed to the rotary magnet via **C1**, **E6**, and *H*5. At the first rotary step, the pre-operate winding of *C* is again short-circuited at **NR2**, and the *C* relay is now held during the rotary train by the current pulses in its 5 Ω winding. The operation of **NR3** short-circuits the 200 Ω coil of relay *WS* but an alternative holding circuit is provided via **WS2**, **N2**, **NR2**, etc., to earth.

Relay *C* releases at the end of the rotary train and at *C*3 applies the 900 Ω coil of relay *H* to the *P* wiper. At the same time the *E* relay circuit is broken at *C*4 and the *E* relay commences to release. If the line is engaged, *H* cannot operate due to the absence of battery on the *P*-wire, and, when *E* falls away after its release period, relay *G* is operated from the earth at **B4** via **N3**, **NR2**, *E*3, and *H*6. **G1** applies busy flash battery to the positive line and **G2** applies busy tone to the 570 Ω winding of relay *A* for transmission to the calling subscriber.

If the line tested is disengaged, relay *H* operates and holds to the earth at **B4** via *F*6, **H1**, and **N3**. **H2** applies a guarding and holding earth to the *P*-wire of the seized line, whilst the speaking pair is switched through to the called party at **H3** and **H4**. **H5** disconnects the rotary magnet circuit to prevent an extra rotary step which may occur due to any momentary release of relay *A* after switching. When *E* releases, relay *J* is operated via **H6**, and ringing current is now applied to the called party's line by the operation of **J1**. (**J2** applies ringing tone to the caller.) At the same time the release of *E*7 allows relay *C* to operate by removing the short-circuiting earth from its 700 Ω winding.

When the called party replies, relay *F* operates due to the passage of direct current round the loop. **F6** removes the short circuit from the 400 Ω winding of *F* which holds in series with the *H* relay. **F7** and **F8** switch the lines through and **F1** and **F2** complete the circuit for relay *D*. **D3** and **D4** reverse the current in the calling loop for supervision purposes, whilst **D1** allows *E* to re-operate to the battery at the vertical magnet (via **C4**). The operation of **E2** applies positive battery to the *P*-wire for metering purposes, whilst **E4** temporarily removes the earth from the *P*-wire during metering. **E3** disconnects the circuit for relay *J* which, after its slow release period, disconnects the positive battery from the *P*-wire at *J*3 and replaces the normal earth condition. The circuit is now established for conversation, the *A*, *B*, *C*, *D*, *E*, *F*, and *H* relays (plus *WS* if concerned) being held for the duration of the call.

If the called party replaces his receiver first, relay *D* releases and at *D*2 lights the called-subscriber-held supervisory lamp and brings in an audible alarm if this condition persists. The replacement of the calling subscriber's receiver releases relay *A* which in turn releases *B*. The release of *B*4 now disconnects the holding circuits for relays *WS*, *F*, *H*, and *E*, whilst *B*1 disconnects relay *C*. *E*8 completes the circuit for the rotary magnet to home the selector. The guarding and holding earth is removed from the incoming *P*-wire by the release of *B*2, but is replaced at *C*2 when the *C* relay restores to normal. This earth is maintained to provide a guarded release feature until the *N*4 springs restore when the switch reaches its normal position. The period between the release of *B*2 and *C*2 provides a definite break of the order of 30 msec on the *P*-wire to ensure the release of all preceding selectors.

200-line Final Selector with 2-10 P.B.X. Facilities. Where a subscriber has a Private Branch Switchboard with two or more lines to the public exchange, arrangements must be made for a calling subscriber to have automatic access to all the available lines in the P.B.X. group. Ordinary final selectors of the type so far considered are designed to give both vertical and rotary stepping under the control of dialled impulses, busy tone being returned if the selected line is engaged. On final selectors serving P.B.X. groups, facilities are required whereby, if the first line of the P.B.X. group is engaged, the selector

will automatically search over the remaining lines of the P.B.X. group before returning busy tone to the calling subscriber. By far the greatest majority of P.B.X.s have less than ten exchange lines, and the most common type of P.B.X. final selector is consequently designed to cater for groups of up to ten lines. A typical 2–10 line in the group be dialled. P.B.X. subscribers often require to connect certain priority or emergency extensions (e.g. the watchman's office, etc.) through to the exchange at night when the P.B.X. switchboard is unstaffed. In order to provide incoming service to such night service extensions, any exchange line number, other than the first

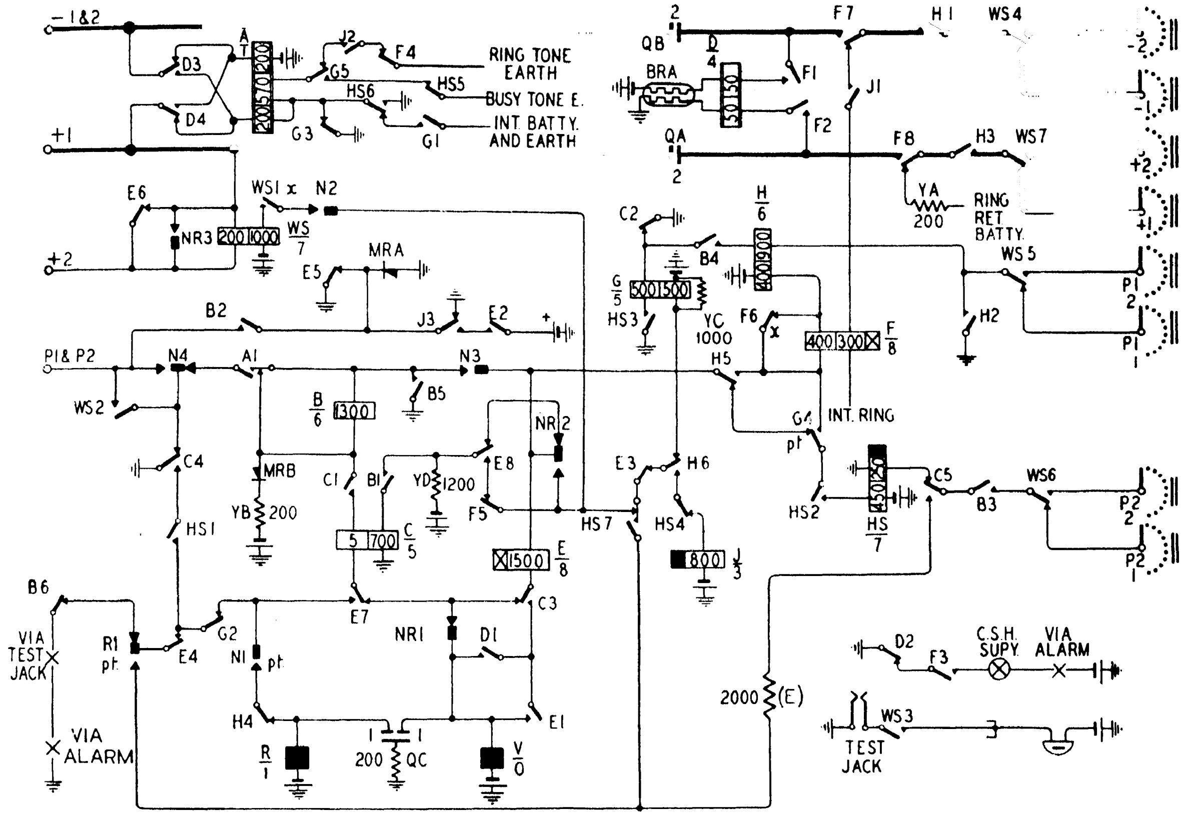


FIG. 358. 200-LINE FINAL SELECTOR CIRCUIT WITH 2–10 P.B.X. FACILITIES (2000 TYPE)

P.B.X. final selector of the 200-line type is illustrated in Fig. 358.

Facilities. The 2–10 P.B.X. final selector provides for the usual requirements of a final selector, e.g. vertical and rotary stepping under the control of the subscriber's dial, automatic ringing circuit, transmission bridge, and so on. In addition, an extra relay (*HS*) is introduced to provide automatic hunting over the lines of a P.B.X. group. The circuit arrangements are such that ordinary lines and P.B.X. lines may be intermixed on the same level, a discriminating feature being provided so that the selector behaves as an ordinary final selector when a non-P.B.X. line is dialled, but gives automatic hunting over the lines of a P.B.X. group should the number of the first line in the P.B.X. group, may be allocated for night service and the numbers published separately in the telephone directory. The final selector circuit is designed so that, if any intermediate number in a P.B.X. group is dialled, the hunting feature is inoperative. Hence, if a particular night service number is engaged, busy tone is returned to any caller dialling this number.

The circuit illustrated in Fig. 358 is built up of the standard elements already considered with the addition of a "hunt start" relay *HS* and an associated interacting relay type of drive circuit on the lines of Fig. 276.

Circuit Description. Relay *A* responds to the impulses received from the calling subscriber and at *A1* operates *B*. *B1* in turn pre-operates relay *C*

to the 1200 Ω battery at *YD*. The vertical magnet responds to the impulses repeated at the *A*1 contact, and, at the end of the impulse train, relay *C* releases due to the cessation of current pulses in its 5 Ω winding. (The pre-operate winding of *C* is short-circuited at the first vertical step by the application of earth from ***B*5** via contacts ***N*3**, *NR*2, and *E*8.) When *C* releases at the end of the vertical train, a circuit is provided for the *E* relay which operates to the vertical magnet battery via *NR*1 and *C*3 to the earth at ***B*5**. ***E*7** changes over the impulsing circuit to the rotary magnet. At the same time ***E*8** removes the short circuit from the 700 Ω winding of *C* and allows the latter to re-operate. At the first rotary step, contacts ***NR*2** change over and again short-circuit the 700 Ω winding of *C* which is dependent during the rotary impulse train on the current pulses in its 5 Ω coil.

At the end of the rotary train, relay *C* releases. If the number dialled is that of an "ordinary" subscriber's line, the absence of battery on the *P*2 bank prevents the operation of relay *HS*. If the outlet is free, relay *H* operates on the release of *C*2 as already described for earlier circuits. The restoration of *C*3 disconnects the circuit of relay *E* which also releases after a period of lag. *E*8 now allows relay *C* to re-operate on the 700 Ω winding, whilst *E*3 completes the circuit for the *J* relay. ***J*1** completes the automatic ringing circuit, and, when the called subscriber replies, relay *F* operates and disconnects both ringing current and ringing tone at ***F*7**, ***F*8**, and ***F*4** respectively. Relay *D* now operates to the called subscriber's loop and at ***D*1** re-operates *E*. ***E*3** now releases relay *J*, and positive battery is applied to the *P*-wire at ***J*3** during the release lag of relay *J*. The potentials of the negative and positive lines to the calling party are also reversed for supervision purposes.

If the called party's line is engaged, relay *H* cannot operate due to the absence of battery on the *P*1 bank, and in due course, when relay *E* releases, a circuit is provided for the busy relay *G* via *H*6, *E*3, *HS*7, ***NR*2**, ***N*3** to the earth at ***B*5**. *G* operates over this circuit and at ***G*5** applies busy tone to the 570 Ω coil of relay *A*. The normal earth on one line coil of *A* is replaced at **G1** and **G3** by interrupted battery and earth to provide the busy flash facility.

If the number dialled is the first number of a P.B.X. group, relay *HS* operates to the marking battery on the *P*2 bank on the release of *C*5 at the end of the rotary train (see also Fig. 276). If the outlet is free, *H* operates in the usual way and the holding circuit of *HS* is broken at ***H*5**. If, on the other hand, the first line of the P.B.X. is engaged, relay *H* cannot operate, and, when relay *E* releases, a circuit is provided for the operation of relay *C* due to the removal of the earth at contact *E*8. The operation of **C4** now provides a circuit for the rotary magnet via ***HS*1**, *G*2, **N1**, and *H*4. Towards the end of the rotary magnet operate stroke, contacts ***R*1** change over and in so doing provide a circuit for relay *G* from the earth at **C4** via ***HS*1**, *E*4, **R1**, ***HS*7**, *E*3, and *H*6. The **G2** contacts disconnect the rotary magnet circuit. If the outlet on which the wipers now stand is free, relay *G* holds in series with *H* until the latter operates (from the earth at ***HS*3**) to the battery on the *P*1 bank. When *H* operates, the application of earth at ***H*2** releases *G* which, in turn, breaks the holding circuit for relay *HS* at *G*4. The release of *HS*4 allows relay *J* to operate, and ringing current is applied to the called subscriber's line.

If the second outlet to the P.B.X. group is engaged, relay *G* releases when the *R*1 contacts restore. The restoration of *G*2 again completes the rotary magnet circuit and a further rotary step is made. The process continues until all the lines in the P.B.X. group are tested. The last line of the P.B.X. group is marked by an earth on the *P*2 bank. When the wipers are stepped to this position, relay *G* is held from this earth via ***B*3**, **C5**, ***HS*7**, *E*3, and *H*6. Further rotation is thereby prevented, and, if this last line is busy, *HS* releases and busy tone and flash are transmitted to the calling party.

If any line other than the first in a P.B.X. group is dialled, the absence of battery on the *P*2 bank prevents the operation of relay *HS* and the selector behaves exactly as for a call to an ordinary line. The operation of the circuit during release is similar to the circuits already considered. The 2000 Ω resistor (*E*) is included to prevent the application of full earth to the *P*2 bank when the ***R*1** contacts operate at the first step of automatic hunting over a P.B.X. group. Hence, if a second final selector is testing the first line of the group, the correct conditions are maintained for establishing the hunting feature. The operate current of the *HS* relay and the value of the resistor in the battery supply to the *P*2 bank of the first line in a P.B.X. group are so adjusted that it is possible for three *HS* relays in the same final selector group to operate simultaneously.

11-and-over P.B.X. Final Selector. An alternative form of P.B.X. final selector is required to cater for P.B.X. groups which have more than 10 exchange lines. In the past it has been common practice to provide one type of final selector to

cater for P.B.X.s of from 11 to 20 lines, and a further type of selector for P.B.X.s of more than 20 lines. The current standard arrangement is to provide one final selector which can be used for any type of P.B.X. with 11 or more exchange lines. Fig. 359 shows a typical circuit of an "11-and-over" type P.B.X. final selector, which provides facilities for automatic hunting over P.B.X. groups of from 11 to 200 lines.

Facilities. Provision is made in the circuit for dial control of the initial vertical movement of the wiper carriage, and for automatic search over all the bank contacts of the selected level. Dual testing facilities are provided so that it is possible to accommodate up to 20 lines per level. If all outlets on the primary level are engaged, the selector automatically steps to the 12th rotary position, releases, and then drives vertically to the next level allocated to the P.B.X. group. If there are no free outlets on this level, the switch again steps to the 12th rotary position, releases, and automatically drives to the third group of 20 lines. This process continues until the last level allocated to the particular P.B.X. group is reached. If there are no free outlets on this last level, the wipers are stepped to the 11th rotary position and busy tone is returned to the caller.

The circuit is designed so that the lines of one particular P.B.X. group can be placed on any convenient levels of the bank, the intervening levels being occupied, if necessary, by other P.B.X. groups.

The final impulse train is not required for the operation of the selector, and is therefore absorbed but, for directory purposes, it is usual to allocate No. 1 as the final digit in a large P.B.X. group in order to maintain a uniform number of digits throughout the exchange area. (It should be noted that 100 numbers of each 200-line final selector group are in the exchange numbering scheme. The remaining 100 lines are given arbitrary numbers outside the main scheme.) The circuit arrangements are such that it is not possible to accommodate more than one P.B.X. on any one level of the selector.

Apart from the system of rotary drive, dual testing and automatic search over a number of levels, the facilities are similar to those of final selectors of the ordinary type.

There are 15 relays for control purposes. The *A*, *B*, *C*, *D*, *F*, and *J* relays perform their usual functions, the additional relays being utilized as follows:

Relay *E*. Rotary drive control relay.

Relay *HA*. Testing and switching relay for odd-numbered outlets.

Relay *HB*. Testing and switching relay for even-numbered outlets.

Relay *DR*. Rotary drive start relay.

Relay *RN*. Vertical drive start relay.

Relay *DW*. Metering relay and level marking relay.

Relay *DX*. Level marking relay.

Relay *DY*. Level marking relay and busy relay.

Relay *DZ*. Level marking relay and busy relay.

Circuit Elements. The basic circuits for the control of the initial vertical stepping, for supervision, metering, and so on, are the same as on previous selectors. The dual battery testing circuit and the interacting relay rotary drive circuit have been considered in Fig. 277. The method of providing automatic search over a number of predetermined levels follows the arrangements shown in Fig. 278.

Circuit Description. When the circuit is seized, relay *A* operates to the loop extended from the preceding selectors. ***A*1** operates *B* and ***B*1** operates *C*. During the first impulse train, relay *A* is released at each break impulse and repeats the impulses to the vertical magnet. At the first vertical step, the pre-operate winding of relay *C* is short-circuited by contacts ***N*2** but the relay holds during the impulse train from the pulses in its 5 Ω winding. At the end of the vertical train, *C* releases and at *C*2 operates *DR* to the earth at ***B*5** via ***N*3**, *RN*2, *F*4, *HA*5, and *HB*3. ***DR*2** now completes the circuit for the rotary magnet and in due course contacts ***R*1** operate. A circuit is now provided for the operation of the *E* relay on its 500 Ω winding to the earth at ***B*4**. At the same time the operation of ***DR*4** allows the *C* relay to re-operate on its 700 Ω winding. ***C*3** connects the 200 Ω winding of relay *E* in series with relays *HA* and *HB* to the *P*1 and *P*2 wipers. If one or both of the outlets on which the wipers are resting is free, relay *E* holds in series with the appropriate switching relay to the battery in the subscriber's line circuit, whilst the current over this circuit operates the switching relay *HA* or *HB*. If both outlets are free, both *HA* and *HB* may operate, but contact ***HA*5** breaks the holding circuit of relay *HB*, so that in these circumstances the circuit discriminates in favour of the *P*1 bank outlet. The operation of ***E*1** disconnects the rotary magnet circuit, the rotary magnet is de-energized, and further stepping is prevented by the operation of ***HA*7** or ***HB*7**.

Relay *J* operates to ***HA*1** or ***HB*5**, whilst the hold circuit for the *DR* relay is disconnected at ***HB*3** or ***HA*5**. When *DR* releases, the automatic ringing circuit is completed at *DR*8. In due course, the called subscriber answers, relay *F*

*operates, and at **F3** and **F6** disconnects the ringing* current and extends the called subscriber to the transmission bridge. Relay D now operates to the called subscriber's loop, and, in addition to reversing the potential on the incoming negative and positive wires for supervisory purposes, a circuit is provided for relay DW by contact **D1**. **DW6** releases relay J, whilst **DW4** applies positive metering battery to the P-wire during the release lag of J.

If both outlets of the first rotary position are busy, relay E releases due to the absence of battery potential on the P1 or P2 banks. At E1 the rotary magnet circuit is re-established and the wipers are moved to the second rotary position. Stepping and testing continue in this manner until all the outlets on the level have been tested. When the wipers reach the 11th rotary position, the S springs operate and at **S3** operate relay RN. Contacts **RN1**, **RN4**, **RN5**, and **RN6** connect the discriminating relays DW, DX, DY, and DZ to the 11th contacts of the bank. These contacts are marked by connecting them to earth, the particular marking depending on the level to which the wipers are required to step in order to continue search over the P.B.X. group. The discriminating relays are held via their own contacts (**DW1**, **DX1**, etc.) to the earth at **B4** under the control of contact DR2 (DR being released by the operation of **RN2** at the 11th rotary step). A circuit is now provided for the rotary magnet via R1, **RN3**, DR7, the 5Ω coil of relay C, and one or other of contacts **DW2**, **DX4**, or **DY3** to the earth at **B5** via contacts V1. The wiper carriage is thereby stepped to the 12th rotary position and the carriage restores to normal.

The restoration of the off-normal springs N3 now allows relay RN to release, and RN3 completes a circuit for the operation of the vertical magnet through contacts of the discriminating relays (DW2, DX4, etc.), the V1 springs and the 5Ω winding of the C relay. The vertical magnet interacts with the vertical interrupter contacts (V1)

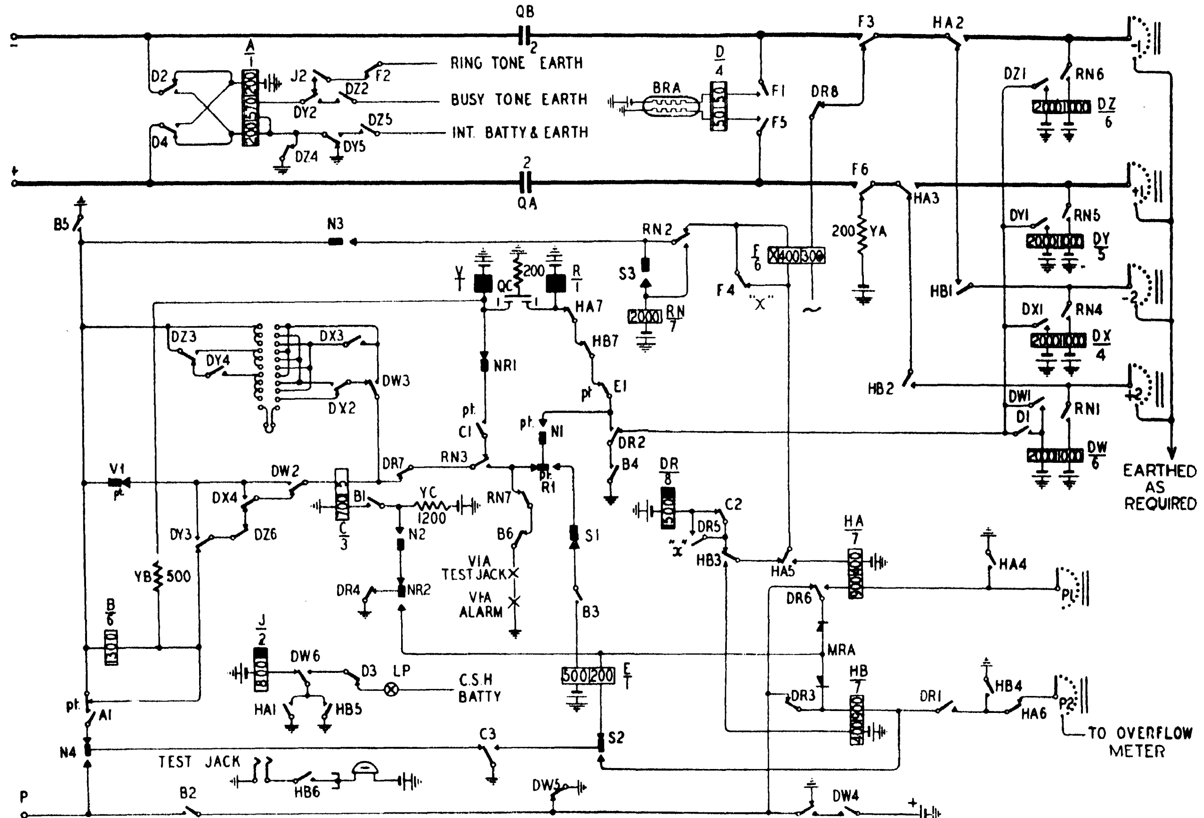


Fig. 359. 11-and-over P.B.X. Final Selector Circuit (2000 Type)

until such time as the $V1$ contacts and the C relay are short-circuited by an earth applied via other contacts ($DW3$, $DX2$, $DZ3$, etc.) of the discriminating relays through the vertical marking bank. Relay C now releases and at $C1$ disconnects the vertical magnet circuit. $C2$ allows relay DR to re-operate and the wipers cut into the selected level as described previously.

The above circuit operation can perhaps be clarified by considering a hypothetical arrangement for a P.B.X. of 60 lines. Assume that the primary level of the P.B.X. group is, say, 8. This level will accommodate the first 20 circuits of the P.B.X. group. Assume also that the second group of 20 circuits is accommodated on level 3 and that the third and final group of lines on the P.B.X. is on level 5. If all outlets on level 8 are engaged, the wipers step to the 11th rotary position. The contacts of the discriminating relays are so arranged that the relays must be operated in the following combinations in accordance with the level required:

1 Relay DY	6 Relays DX, DZ
2 Relays DW, DX, DY	7 Relays DW, DZ
3 Relays DX, DY	8 Relays DW, DX
4 Relays DW, DY	9 Relays DX
5 Relays DW, DX, DZ	0 Relay DW

Last Level—Relays DY, DZ

In this particular example it is desired that the wipers should cut in on the 3rd level to test the second group of 20 lines. Earth is therefore connected to the -2 and $+1$ eleventh step contacts of level 8 so that, when the wipers are stepped to the 11th rotary position, relays DX and DY are operated. DX and DY hold via contacts $\boldsymbol{DX1}$ and $\boldsymbol{DY1}$ respectively, and the switch steps to the 12th rotary position over the circuit formed by contact $\boldsymbol{DX4}$. The wiper carriage now restores to normal, and on the release of RN the circuit for the vertical magnet is completed via contacts $NR1$, **C1**, $RN3$, $DR7$, 5 Ω coil of C relay, $DW2$, $\boldsymbol{DX4}$, and $V1$ to the earth at $\boldsymbol{B5}$. The V magnet and $V1$ springs interact to step the wiper shaft vertically until the vertical marking wipers reach the 3rd level. At this point earth is extended from $\boldsymbol{B5}$ via $DZ3$, $\boldsymbol{DY4}$, $\boldsymbol{DX2}$, and $DW3$ to short-circuit the $V1$ contacts, thereby terminating the vertical drive and enabling rotary hunting to take place over the 3rd level.

If all outlets on the 3rd level are engaged, the wipers again step to the 11th rotary position, and, since it is next required that the wipers should step to the 5th level, earth is connected to the $+2$, -2, and -1 bank contacts. This allows relays DW, DX, and DZ to operate and lock. The wiper carriage is restored as before and automatic vertical stepping is established as soon as the wiper carriage reaches normal. The vertical motion continues until the wipers reach the 5th level when the $V1$ contacts are now short-circuited by $\boldsymbol{DZ3}$, the vertical marking wipers, $\boldsymbol{DX3}$ and $\boldsymbol{DW3}$. Rotary drive over the 5th level follows as before and, if all lines on this final level are engaged, the earth on the $+1$ and -1 contacts operates relays DY and DZ. $\boldsymbol{DZ6}$ prevents any further rotary stepping, whilst at $\boldsymbol{DY2}$ and $\boldsymbol{DZ2}$ busy tone is returned to the calling subscriber. An overflow meter is connected to the 11th step $P2$ bank of the last level and is operated during the release lag of C to record the congestion condition.

It has been seen that the first level over which rotary search takes place is determined by the digit dialled, and that the last level is determined by the position of the overflow meter. It is clear that these two levels must remain the first and last respectively, whatever the order of the intermediate levels. It is, however, possible to reduce the hunting time on very large P.B.X. groups by altering the position of the marking earths on alternative shelves of a final selector rack so that the intermediate levels are tested in a different order.

Auto-auto Relay Set. Fig. 360 shows a typical circuit of a relay set suitable for use on outgoing junctions to a distant automatic exchange. Provision is made for:

(*a*) Guarding and holding the preceding train of selectors under the control of the calling subscriber's loop.

(*b*) Repeating the impulses from the calling subscriber's dial to the junction circuit.

(*c*) Guarding and holding the junction against intrusion by other selectors.

(*d*) Positive battery metering when the called subscriber replies.

(*e*) A transmitter feeding bridge for the calling party.

(*f*) The repetition back of the answering supervisory signal when the called party replies.

(*g*) The backward repetition of busy flash should the call encounter busy conditions.

Circuit Elements. All the more important features of the circuit have already been considered in previous chapters, e.g.:

Impulse repetition bridge with two-stage drop-back and rectifiers for improving subsequent pick-up (Fig. 220).

Two-relay guard on outgoing junction (Fig. 300).

Repetition of supervisory signal through impulse bridge (Fig. 309).

Repetition of busy flash through bridge (Fig. 312).

Circuit Description. The extension of the calling subscriber's loop to the relay set operates relay *A*, and the **A2** contact completes the circuit for the operation of relay *B*. **B1** operates relay *J* and **J1** in turn operates *JA*, in readiness for metering at prevents the operation of *DD* during impulsing (i.e. during the period between the operation of *BB* and the later operation of *MD*). **CA2** completes the circuit for relay *BB*, and **BB2** operates the metering delay relay *MD*.

Relay *C* releases during each interdigit pause period, and at *C*2 disconnects the circuit of relay

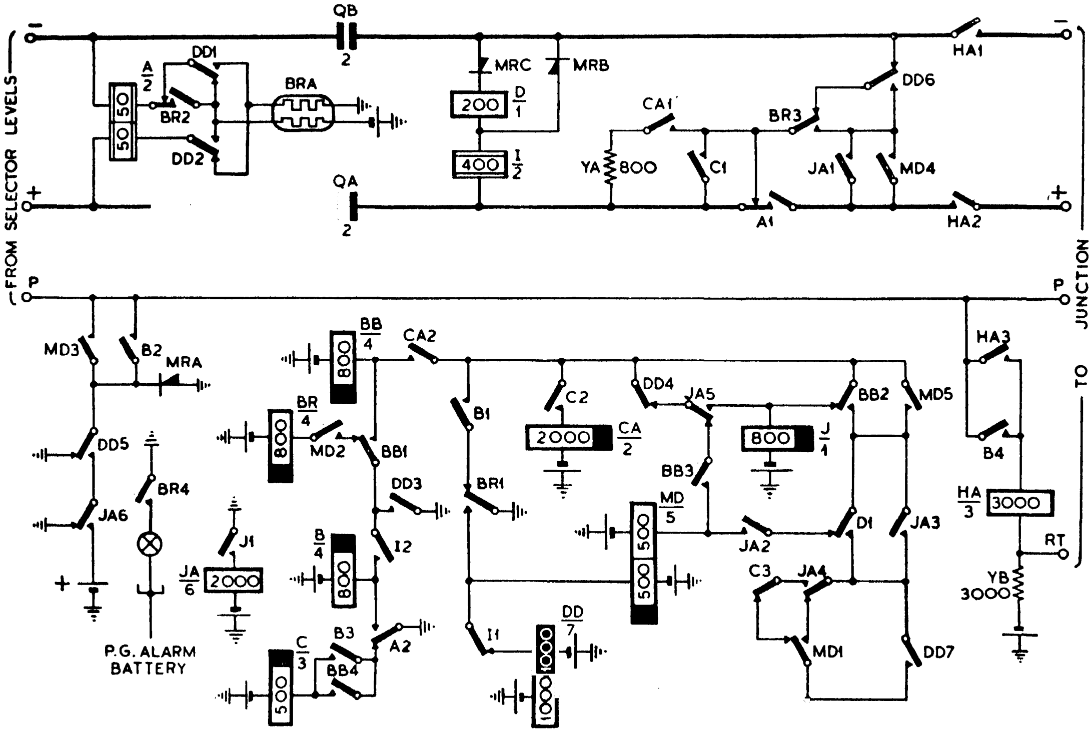


FIG. 360. AUTO-AUTO RELAY SET

a later stage. **B2** applies the guarding and holding earth to the *P*-wire.

Contact **B4** operates *HA*, which now holds to the earth on the *P*-wire for the duration of the call. Contacts **HA1** and **HA2** complete the outgoing loop to the junction. Relay *HA* is provided primarily so that the junction can be isolated from the relay set for routine test purposes. It does not perform any function during the normal operation of the relay set, but the application of an earth to the *RT*-lead during routine testing prevents the operation of *HA*, and dissociates the relay set from the junction.

Relay *C* operates during the first release period of the *A*2 contact, and its slug enables it to hold throughout each train of impulses. The **C1** contact short-circuits relays *D* and *I* to cut out these relays from the impulsing loop. Contact **C2** completes a circuit for relay *CA*, whilst **C3** *CA*. During the slow releasing period of relay *CA*, an 800 Ω resistor (*YA*) is connected in parallel with relays *D* and *I* across the − and + wires. This prevents the momentary release of the distant exchange *A* relay on long junctions which tends to occur when the impulsing loop is directly replaced by the high impedance of relays *D* and *I* at the end of the train. (See under "subsequent pick-up"—Chapter VI.)

At the end of impulsing, the restoration of relays *C* and *CA* allows relay *I* to operate to the loop current, and **I2** completes a holding circuit for relay *BB*. (Relay *I* also operates when *C* releases between impulse trains.)

When the called subscriber answers, relay *D* operates to the reversal of line current from the distant exchange, and at **D1** disconnects the circuit of relay *MD*. The latter is slow to release, and, after its period of lag, earth is extended via

D1 and *MD*1 to operate relay *DD*. This delay feature is introduced to guard against false operation of the meter should relay *D* momentarily operate as a result of current surges on the junction. Contacts ***DD*1** and ***DD*2** now reverse the line current towards the caller for supervision purposes, whilst ***DD*5** applies the positive metering potential to the *P*-wire. ***DD*4** disconnects the circuit of relay *J*, and after a period of lag *J*1 releases *JA* so that the *JA*6 contact can remove the metering potential. The metering pulse is therefore applied during the release lags of relays *J* and *JA*. The circuit is now established for conversation and is held by relay *B* under the control of the loop applied to the *A* relay.

When the calling subscriber replaces his receiver, relay *A* releases and, at *A*1, disconnects the positive wire of the outgoing junction to release relays *D* and *I* and the distant exchange apparatus. At the same time, *A*2 releases *B* and operates *C*. ***C*2** re-operates relay *CA*. The restoration of relay *D* disconnects (at *D*1) the circuit of relay *DD*, and the latter releases. *DD*4 now re-establishes the operate circuit of relay *MD*.

The operation of *CA* provides a holding circuit for relay *BB* during the release period of relay *B*. In due course *B* releases, and at *B*1 disconnects the circuit of relays *CA*, *BB*, and *MD*, which release slowly. The restoration of *MD*3 disconnects *HA* and, similarly, the restoration of *B*3 disconnects the circuit of relay *C*. The circuit now restores to normal. It should be noted that the junction is guarded against intrusion at the end of a call for the release periods of relays *B* and *MD*.

Should a call encounter the engaged condition, relay *I* releases during each period of busy flash, and re-operates during the busy tone period. At the first release of *I*2, relay *BB* releases and, at *BB*1, prepares the circuit for relay *BR*. When relay *I* re-operates to the next tone period, the closure of ***I*2** completes the circuit for the operation of *BR*. ***BR*1** disconnects the circuit of relay *J* and completes a holding circuit for relay *MD*. The next release of relay *I* completes (at *I*1) the circuit for the operation of relay *DD*. The ***DD*1** contact, in conjunction with the ***BR*2** contact, applies busy flash to the incoming positive wire. Relay *DD* releases during each period of busy tone.

If the subscriber clears during busy flash, the circuit is not released until the next tone period, i.e. by the operation of relay *I* and the release of relay *DD*. The release guard under busy conditions is provided by the sum of the release lags of relays *MD* and *BR*.

The complexity of the auto-auto relay set is due partly to the necessity of providing for unusual conditions of operation, and partly to avoid the transmission of clicks to the originating subscriber during the establishment of a call. The following features are illustrative of problems encountered in the design of the circuit:

(*a*) Contact ***JA*1** is inserted to prevent clicks due to the momentary release of relay *A* when relay *DD* operates.

(*b*) Contact *JA*2 prevents the operation of relay *MD* (via *D*1) during the release of the circuit. This is necessary to avoid the operation of relay *MD* prior to the release of relay *DD*, which would result in interaction between relays *D*, *I*, and *MD*. This condition would persist if the calling subscriber cleared first, until such time as the called subscriber cleared.

(*c*) Contact ***MD*3** is provided to guard the *P*-wire independent of *B* under busy conditions and after the release of relay *B*.

(*d*) The ***MD*4** contact applies a short circuit across contact *A*1 to guard the negative wire against disconnexion when relay *A* releases during busy flash (and also when the called subscriber flashes).

(*e*) Contact ***DD*3** completes a holding circuit for relay *B* if relay *A* releases when its circuit is changed over, and if the subscriber clears whilst metering is taking place.

(*f*) Contact ***BR*3** (in addition to operating in conjunction with *MD*4 for the short-circuiting of *A*1 during busy flash) also prevents interaction between relays *DD* and *I* during busy flash if the flash period is insufficient to allow relays *C* and *CA* to release.

(*g*) A supervisory lamp with a delayed alarm is provided to indicate lock-up conditions. If, for example, relay *BR* is operated manually, relays *DD* and *MD* are operated by ***BR*1**, and *BR* is held permanently to the earth via ***MD*2**, *BB*1, and ***DD*3**.

EXERCISES XI

1. Draw a diagram of a subscriber's uniselector circuit, and explain (*a*) its operation when an incoming call is received from a final selector, (*b*) why the line relay is made slow-to-release, (*c*) why there is a risk of mis-operation if one of the line relay contacts operates before the other, and (*d*) why some of the uniselector wipers are of the bridging type. (*C. & G. Telephony, Grade II*, 1946.)

2. Describe, with the aid of a diagram, the circuit operation of a 100-outlet group selector from the moment it is seized to the time that the calling loop is extended to the 2nd outlet on level 3. (*C. & G. Telephony, Grade I*, 1945.)

3. Explain the purpose of the following contacts in the 100-outlet group selector circuit illustrated in Fig. 354:

*NR*2, *NR*3, *H*3, *H*5, *B*5.

4. In a group selector circuit certain relays have two windings. Explain, with the aid of a circuit diagram, why the second winding is provided in each case. (*C. & G. Telephony, Grade I*, 1943.)

5. Explain why large availability groups of trunks are more efficient than small groups.

A certain second selector is the tenth choice from a large group of first selectors. A test from the selector test-jack reveals that its positive and negative lines are in contact. Show how you would proceed step by step to localize the fault, assuming it to be finally found in the multiple wiring of a specific first selector. (*C. & G. Telephone Exchange Systems II*, 1948.)

6. The *E* relay in the 200-line final selector shown in Fig. 357 has several functions. State concisely the various functions of the *E* relay and describe the contacts associated with these functions. Why is the *E* relay made slow-to-operate?

7. How is a 200-line final selector used in an automatic exchange in which the subscribers' numbers are grouped in blocks of 100?

With a diagram of the circuit elements, give a description of the circuit operation of such a selector as the last two digits are dialled, and show how the call is directed to the correct contact bank. (*C. & G. Telephony, Grade II*, 1946.)

8. Enumerate the types of final selector usually provided in a large automatic exchange, stating the particular function of each type.

Explain, with reference to a circuit diagram, how rotary stepping is controlled in the type of final selector employed for completing connexions to small groups of lines to private branch exchanges. (*C. & G. Telephony, Grade II*, 1939.)

9. A certain private branch exchange has 35 lines incoming from an automatic (public) exchange. With reference to a diagram of the circuit elements of a suitable final selector, explain how the selector wipers may be made to search for a disengaged line anywhere in the group. Describe any limitations or special facilities that exist in respect of the order of hunting. (*C. & G. Telephony, Grade III*, 1946.)

10. Describe the sequence of operations in the auto-auto relay set of Fig. 360 when the calling subscriber replaces his receiver just after a period of busy tone. Why is it necessary to have such a sequence?

CHAPTER XII

THE NON-DIRECTOR SYSTEM

VARIOUS simple trunking schemes to provide automatic switching in exchanges of up to 10 000 lines have been considered in Chapter I. We have seen that a 4-digit scheme will cater for a *theoretical* maximum of 10 000 lines, whilst an additional group selector stage (i.e. a 5-digit scheme) will increase the exchange capacity up to 100 000 lines. In practice there is a number of miscellaneous requirements which prevent the attainment of these theoretical capacities. In particular, levels must be reserved for providing access to an automanual exchange operator and to many auxiliary services, such as Speaking Clock, Service P.B.X., Phonograms, Enquiries, and so on. For obvious reasons the levels reserved for these various services are maintained as uniform as possible throughout the country.

Allocation of First Selector Levels. The following 1st selector levels are normally unavailable for subscribers' numbers:

Level 1. The first level of 1st selectors has so far been treated as unavailable owing to the danger of mis-routing due to a false initial impulse. (There is a fairly big possibility that a subscriber may transmit a single impulse during the removal of the handset from the telephone cradle.)

Level 7. At non-director exchanges within 15 miles of the centre of a director area (q.v.), level 7 is reserved for giving access to the director exchanges within multi-metering range.

Level 8. This level is reserved for calls to exchanges in the multi-fee metering area (i.e. to exchanges in the 5–15 mile belt).

Level 9. This level is reserved for giving access (via 2nd selectors) to a number of auxiliary services, such as Phonograms, Service P.B.X., etc. Details are given in later paragraphs.

Level 0. This level is always used for giving access to the automanual board.

In a 4-digit numbering scheme each unavailable 1st selector level represents a loss of 1000 lines in the capacity of the exchange. In a 5-digit numbering scheme the loss is 10 000 lines per 1st selector level. Since there can be only five (or possibly six) 1st selector levels allocated to the local subscribers, it follows that the practical capacity of a 4-digit scheme is 5000 (or 6000) lines, whilst the ultimate size of a 5-digit scheme is ten times this number.

The community of interest with adjacent exchanges may also place further restrictions on the levels which are available for obtaining access to local subscribers. If, for example, at any particular exchange there is a high community of interest with, say, three adjacent exchanges, then it may be desirable to allocate a 1st selector level to provide direct access to each of these exchanges by the dialling of a single-digit code. In other circumstances, the traffic to nearby exchanges (within the 5-mile circle) may not be so great, and it may be permissible to route these junctions from 2nd selector levels. Generally speaking, single-digit codes are used wherever possible for routes carrying very heavy traffic, but, if this unduly restricts the local numbering range, 2-digit codes may be unavoidable. It is undesirable to utilize 3-digit codes for obtaining access to exchanges within the 5-mile circle.

In general, the numbering scheme of any exchange area is designed to meet the 30-year development forecasts. Thus a 4-digit scheme is normally adopted when the 30-year development figure does not require more than 6000 lines (or 5000 lines when the exchange is near a director area). Where the development exceeds this figure, a 5-digit scheme is necessary and will cater for up to a maximum of, say, 50 000 lines. In the past it has not been uncommon to have a mixed 4- and 5-digit scheme in one exchange area. Under certain conditions this arrangement provides material economies in the quantity of switching plant required.

Service Levels. The large number of auxiliary services requires 2nd, and sometimes 3rd, selectors from the 9th level of 1st selectors. The various service levels have been standardized as follows:

Level 91—*Enquiries.* This level is used for general service enquiries and gives access to a special suite of positions at the automanual exchange.

Level 92.—*Service P.B.X.* Callers dialling "92" are routed either to special positions set aside in the automanual exchange or to a separate P.B.X. installation at the Telephone Manager's Office.

Level 93—*Rural Party Lines.* In the past it has been the policy to cease, as far as possible, all party lines when a manual exchange is converted to automatic working. Any rural party lines which cannot be so terminated at the conversion are

connected to the manual board, and automatic subscribers can obtain access to the special position by dialling "93."

Level 94—*Trunks.* In certain cases subscribers dial "94" to obtain access to the Trunk Exchange, and dial "0" for general assistance and for toll calls. Where joint trunk working is in force, however, the subscriber dials "0" for all trunk and toll calls, and the "94" level is not used (except in certain cases by manual exchange operators).

Level 95—*Telephone-Telegrams.* This service enables Sub-Post Offices to pass telegrams by phone to the main Telegraph Office of the district. In some cases the volume of such traffic is very small, and can be routed via the normal "0" level circuits.

In some areas the "95" level is extended to 3rd selectors in order to provide levels for additional services. Under these conditions the following codes are used:

Level 951—*Telephone-Telegrams.*
Level 952—*Speaking Clock.*
Level 953—*Directory Enquiries.*

Level 96—*Faultsmen's Ring-back Circuit.* In some exchanges equipment is installed whereby the engineering faultsmen can dial "96" to test subscribers' bells. When the equipment is seized, the caller receives a distinctive tone, and, on replacing the receiver, ringing current is applied to the line for as long as may be necessary to test and adjust the bell. The ringing is tripped when the receiver is lifted from the cradle-switch.

Level 97—*Engineering Fault Complaint and Repair Service.* This level gives access to engineering testing officers, who receive complaints of plant faults and arrange for attention to be given to faulty lines. (This facility is as yet in the experimental stage.)

Level 98—*Telex.* This level is reserved for providing access to a special Telex position for establishing teleprinter connexions which cannot be completed automatically.

Level 99. This level formerly gave access only to the Test Desk, and was provided for the use of faultsmen and engineering maintenance officers. In future, the "99" level will be extended to 3rd selectors to provide an *emergency service* on the "999" level. The remaining 3rd selector levels (i.e. 990–998) can be used for giving access to different positions on the Test Desk (e.g. 991, 992, and 993 might be used to give access to three different fault distribution positions, whilst 995 might be arranged to give access to an Advice Note testing position).

Level 90—*Phonograms.* This level gives access to the main telegraph office of the district, and provides facilities for telephone subscribers to dictate messages for transmission by telegraph.

Up to the present, the standard service level arrangements have not been available at non-director exchanges which are served by a remote manual board. In these circumstances it is usually not economical to provide a large number of separate groups of junctions to the distant auto-manual exchange. If, however, only one service is required (e.g. Enquiries), then the 9th level of the 1st selectors at the automatic exchange may be routed direct to the appropriate service at the automanual exchange—the second digit of the standard code being inoperative.

Trunking Diagrams. We are now in a position to examine the detailed trunking arrangements of a typical exchange, but before proceeding to do so it is desirable to explain some of the conventions used on trunking diagrams.

It is not usual to include the final selectors on such diagrams. Each group of final selectors always has a common multiple which gives access only to the subscribers' lines within the group. Their inclusion on a trunking diagram merely complicates the picture and does not add to the information. It is sufficient to show the numbers of the final selector groups alongside the levels of the appropriate 2nd or 3rd selectors.

The bank multiple of the selectors forming the earlier switching stages of an exchange is often divided into several different portions. Thus, one portion of the multiple can give access to one particular group of outgoing circuits on a particular level, whilst another portion of the multiple gives access to a different group of circuits on the same level. Moreover, by dividing the multiple into several different portions, it is possible to bar access to certain levels from one or more groups of selectors.

To illustrate, in Fig. 361 the 1st selectors are divided into four distinct groups. There is a common multiple on levels 2 to 5 which is accessible from all 1st selectors. (This is shown by a fine connecting line between the levels of the four groups of selectors.) Level 9, on the other hand, requires a separate group of circuits from each of the four groups of 1st selectors. Space and clarity prohibit the use of separate lines to show each of these outgoing groups, so it is usual on a trunking diagram to show the connexions to the banks as illustrated. On other levels (e.g. level 7 of 1st selectors in Fig. 361), it may be necessary to provide a common multiple between two groups of 1st selectors, a separate multiple for the third

group, and no outlets at all from the fourth group of selectors.

Where a level is not numbered, it usually indicates that the level is spare and, similarly, where there is no external line to a particular level, it indicates that this level is not wired out to the next switching stage.

Typical Trunking Scheme. Fig. 361 shows a typical trunking diagram for a non-director exchange equipped for 3400 lines. To avoid complicating the diagram, it has been assumed that, apart from the "9" and "0" level services, the only outgoing routes from the exchange are within the 5-mile circle, i.e. there are no multi-metering problems.

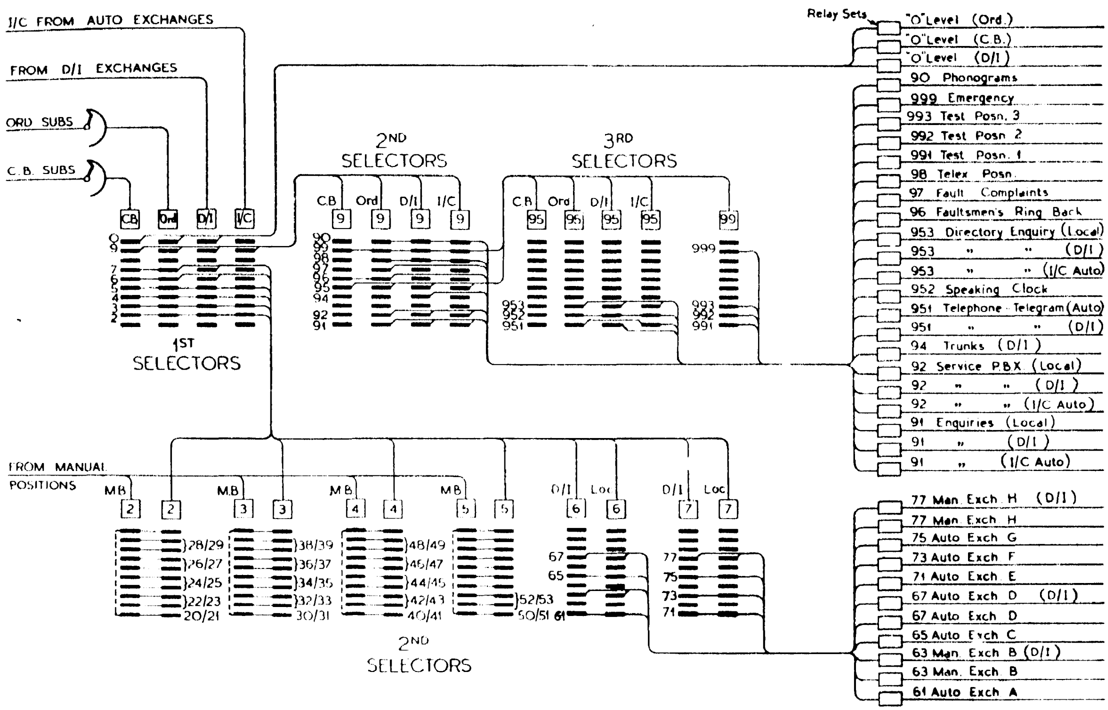


FIG. 361. TYPICAL TRUNKING DIAGRAM OF 4-DIGIT NON-DIRECTOR EXCHANGE

The 1st selectors are divided into four main groups. The first group (C/B) serves the coin-box subscribers, and the outlets from the coin-box uniselectors are graded out to the 1st selectors in this group. The second group (Ord.) is similarly connected to serve the ordinary (i.e. non-coin-box) subscribers. The third group (D/I) comprises the selectors which terminate the incoming junctions over which distant exchange operators dial to obtain the required number. The fourth group (I/C) provides for the 1st selectors which terminate the incoming junctions from other nearby automatic exchanges.

Level 1 is, as usual, left spare on account of the danger of false initial impulses. Levels 2, 3, 4, and 5 are connected as common gradings to take the traffic from all four groups of 1st selectors. Second selector groups 2, 3, and 4 each give access to five groups of 200-line final selectors (20/21–48/49), whilst there are two further final selector groups on the 5th level 2nd selectors. Thus, the trunking scheme provides for seventeen 200-line final selector groups, or a total of 3400 lines. Levels 3 to 9 of the fifth 2nd selector group are shown spare and are available to meet growth.

To minimize the number of digits to be dialled by the automanual operator, it is usual to provide circuits direct from the manual board to each of the 2nd selector groups. The operator selects the appropriate group in the outgoing multiple, and then (in a 4-digit scheme) dials three digits to obtain access to the required subscriber. These manual board 2nd selectors are shown alongside the subscribers' 2nd selectors, and there is a common multiple which serves both the manual board and the subscribers' selectors.

It is assumed that routes are required to eight

exchanges which can be obtained by the dialling of 2-digit codes, i.e. the outgoing junctions are terminated on the banks of 2nd selectors. Levels 6 and 7 of the 1st selectors are reserved for outgoing junctions, and are trunked to the sixth and seventh 2nd selector groups. It will be noted that on level 6 (1st selectors) the coin-box and ordinary lines have a common group of outgoing circuits, the dialling-in exchanges have a separate group, whilst the incoming circuits from distant automatic exchanges are barred access by the isolation of the 6th level on the 1st selector bank. There are therefore two groups of level-six 2nd selectors. One group serves the dialling-in exchanges, and the other serves the local subscribers (both ordinary and coin-box).

On routes outgoing to a manual exchange it is desirable to return a supervisory signal to a dialling-in operator when the called *exchange* replies, whereas, if the call emanates from an auto subscriber, the supervisory signal returned over the junction must be deferred until the called *subscriber* replies, when it registers the call against the calling party. Under these conditions it is usually preferable to provide two separate groups of outgoing circuits to a manual exchange. The circuit arrangements are such that, on the group accessible only to operators, the supervisory signal is returned when the incoming exchange answers, whilst the other group (which is accessible only to auto subscribers) does not give a supervisory signal when the incoming operator replies but defers this signal until metering is required, i.e. when the called subscriber replies. Levels 63 and 77 are so arranged and give access to two manual exchanges both within the unit fee area.

It is also sometimes necessary to segregate the outgoing routes to distant automatic exchanges. If the called exchange is self-contained and does not provide outgoing junctions to other exchanges from its selector levels (i.e. it is a terminal exchange), then a common group to serve the dialling-in operators and the auto subscribers will suffice. Levels 61, 65, etc., are examples of this condition. If, however, it is possible to dial through a distant exchange to obtain access to a further exchange, then care must be taken to ensure that automatic subscribers cannot establish calls irregularly by dialling through the distant exchange equipment. Provided that the signalling and transmission conditions are suitable, there is no reason why dialling-in operators should not dial through a distant automatic exchange, but, in order to prevent the auto subscribers, it becomes necessary to segregate the outgoing junctions into two separate groups. Level 67 is an example of such a case. When two separate groups are provided, the incoming selectors at the distant exchange can be arranged to prohibit access on the incoming auto group but to permit through dialling on the D/I group.

There are four separate groups of circuits from level 9 of the 1st selectors. These are trunked to four distinct groups of 2nd selectors. This segregation is necessary to provide splitting of the levels both on the 2nd selector banks and, in some cases, on the 3rd selectors.

Level 91 is the general "Enquiry" level. On calls originated by auto subscribers no metering is required, but Operator Hold conditions are necessary. On the other hand, when a "91" call is originated by an operator, it is very desirable that standard supervisory conditions should be returned when the Enquiry telephonist answers. It is also desirable to segregate Enquiry calls from distant automatic exchanges from similar calls originated by local subscribers. Level 91 is normally not accessible to coin-box subscribers, who are instructed to dial "0" for all enquiries. It is therefore necessary to provide three separate groups of "91" circuits as shown in Fig. 361.

Similar requirements are necessary on the "92" level which gives access to the Service P.B.X., and hence the levels are taken out separately.

Level 94 is (in this particular case) required only by dialling-in operators for the recording of demand trunk calls which are later established by reverting the call to the originating exchange and over-plugging.

Level 95 is trunked to 3rd selectors, and the requirements of the 3rd selector levels necessitate the taking out of four separate groups. Level 951 is the Telephone-Telegram Service, and is subdivided into two groups. One group is arranged for non-metering and serves the coin-box, ordinary, and incoming auto groups. The second group of circuits is individual to the dialling-in exchanges and is arranged to give supervisory conditions when the Telephone-Telegram operator replies. In some cases, U.A.X.s (see Chapters XIV, XV, *et seq*) are combined with the dialling-in group of circuits. In this case the equipment at the U.A.X. prevents the supervisory conditions from operating the meter of the calling line.

Level 952 gives access to the Speaking Clock and is common to all groups except the 3rd selectors serving coin-boxes. (It is necessary to ask coin-box users to dial "0" in order to obtain connexion to the Speaking Clock since the calling subscriber can otherwise hear the time announcements without pressing Button A.)

Level 953 is set aside for Directory Enquiries,

and here again no metering is required, but the Operator Hold facility is necessary on auto calls, standard supervision being required on calls from dialling-in exchanges. There are thus three separate groups of circuits to the Directory Enquiry positions.

Level 96 is reserved for the Faultsmen's Ring Back, and one common group of circuits suffices both for the ordinary and for the coin-box lines. Access to these circuits is not required from the dialling-in or incoming-auto groups.

Level 97 is routed to the Engineering Fault Complaint lines at the Test Desk. The service is available only to the ordinary (non-coin-box) lines in the automatic exchange area. Coin-box lines dial "0" as usual.

The 98 level gives access to the Telex position and is available to all groups of 2nd selectors except coin-box lines.

Levels 991, 992, and 993 give access to positions 1, 2, and 3 of the Test Desk, one common group of circuits serving all incoming sources. Level 999 is reserved for emergency calls, and here again one group of circuits suffices.

There are three separate groups of level "0" circuits serving respectively the coin-box lines, the ordinary auto subscribers, and dialling-in exchanges. The "0" level of the incoming selectors from distant automatic exchanges is left disconnected, since it is usual to provide separate high-grade circuits for trunk demand calls direct from the individual exchanges to the trunk switchboard.

Main Switching Circuits. The more common types of selector circuit used in a non-director exchange have already been described in Chapter XI. The standard scheme is designed for positive battery metering on the *P*-wire, and the transmission bridge in the final selector provides for the energization of both subscribers' transmitters on a local call. Normally the train of switches is held backwards by the earth condition applied to the *P*-wire from the final selector. The subscriber's uniselector circuit is that illustrated in Fig. 353. The 1st, 2nd (and if necessary 3rd) group selectors are of the 200-outlet type illustrated in Fig. 355. The type of final selector used is determined by the individual requirements of the exchange. In some exchange areas where a high percentage of the subscribers are of the "business" type, it may be desirable to equip most of the final selector groups with switches of the 2/10 P.B.X. type (Fig. 358). In more residential areas, where there is a smaller proportion of P.B.X.s, some economies can be effected by providing some groups of "ordinary" type P.B.X. final selectors (Fig. 357). If the area contains large P.B.X.s, then it will be necessary to provide one or more groups of "11-and-over" type P.B.X. final selectors (Fig. 359).

Where there are outgoing circuits to a manual exchange it is necessary to provide suitable relay sets on the appropriate selector levels. These relay sets are required primarily to provide a bridge from which the holding conditions can be applied to the train of group selectors (and subscriber's uniselector). In some cases, these relay sets must also convert from the normal loop calling conditions from the subscriber to the required signalling conditions on the junction to the manual exchange. On circuits to a sleeve control automanual board located in the same building as the automatic equipment, the normal sleeve control line terminating relay set provides the necessary holding conditions for the automatic selectors. The detailed circuit arrangements of auto-to-manual relay sets are considered later in Chapter XVII.

Relay sets are also required on all junctions outgoing to distant automatic exchanges. The prime purpose of these relay sets is to provide holding conditions for the local selectors. This in turn necessitates the insertion of a transmission bridge and a means of repeating the subscriber's impulses from the calling side to the junction side of the bridge. Such auto-auto relay sets are shown on levels 61, 65, 71, etc., of Fig. 361.

Although in Fig. 361 the auto-auto relay sets are directly connected to the outgoing junctions, they need not necessarily occupy this position. If, for example, all the levels of one particular 2nd selector group give access to automatic exchanges, then the auto-auto relay sets may be more economically placed between the 1st and 2nd selectors. This principle has been fully discussed in Chapter VIII, and further examples are given later in this chapter.

Satellite Working. It has been stated in Chapter I that material economies in the cost of the line plant can often be obtained if a town can be served by a number of suitably located exchanges with automatic access throughout the network. Fig. 362 illustrates this principle. The upper part of the illustration shows a group of subscribers relatively close together but some distance from the centre of the area. If these subscribers are served by a single exchange located at the centre, then it is of course necessary to provide a pair of wires between each subscriber and this central point. The amount of traffic on each pair of wires is usually very small indeed, so that, even during the busy hour, a considerable proportion of the lines are idle.

If, now, this particular group of subscribers is served by a "satellite" exchange located near the centre of the group, and this satellite exchange is provided with junctions to the main exchange at the centre of the town, then a very much smaller underground cable will serve to carry the traffic from this group of subscribers to the remaining subscribers in the town. (A group of, say, 100 subscribers would require something of the order of 10 to 20 junctions from the satellite exchange to the main switching centre.) The provision of the satellite exchange therefore saves from 80 to 90 per cent of the cable pairs to the centre of the town.

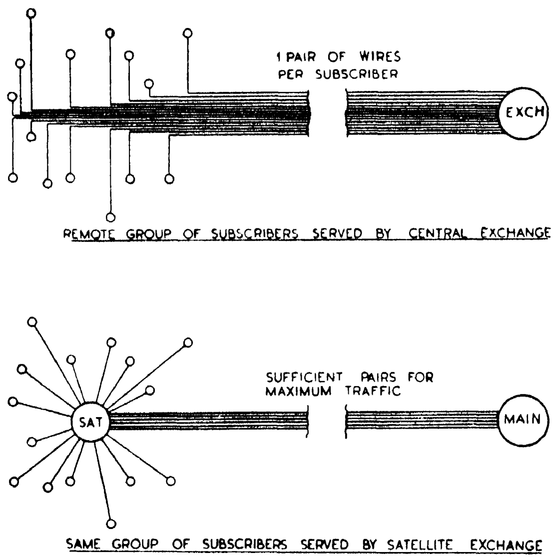


FIG. 362. ILLUSTRATING HOW ECONOMIES IN EXTERNAL LINE PLANT CAN BE OBTAINED BY THE PROVISION OF SATELLITE EXCHANGES

The provision of a satellite exchange is, of course, profitable only if the annual charges brought about by the segregation of the switching plant into separate units are less than the charges on the underground plant saved by this arrangement. With automatic switching, the total quantity of switching equipment required is not materially increased by sub-dividing the plant into a number of separate buildings, but this sub-division does, of course, increase the charges in other directions. For example, the charges on the buildings required to accommodate the plant are increased, as also are the maintenance charges. Nevertheless, in most medium size and large towns it is usually economical to provide a central or *main exchange* and a group of *satellite exchanges* to serve the subscribers on the fringes of the town. In some cases a satellite exchange may not be more than a mile from the central exchange, but this may be economically justified on account of the very high cost of underground plant.

Although it may be desirable on economic grounds to divide the switching plant between a main and a number of satellite exchanges, a town area must be considered as a single unit from the subscriber's point of view. In any given town the various districts merge one into the other and are not clearly defined. Moreover, the satellite exchange area boundaries—which are determined by line plant considerations—do not necessarily coincide with the names of the various suburbs. Usually a very high percentage of the total originated traffic is to subscribers in the town or its suburbs, and the telephone users move freely within the town from one exchange area to the other. It is therefore a primary requirement that the automatic switching scheme should be so designed that subscribers can use the same digits for calling a subscriber's number from any telephone in the town or its suburbs. Hence, the standard practice is to provide a common numbering scheme for the main and for all the satellite exchanges in an area. Such a group of exchanges is said to have a *linked numbering scheme*, and an area served by a group of exchanges with a linked numbering scheme is commonly known as a *multi-exchange area*.

It is useful at this stage to examine the distribution of traffic in a multi-exchange area. In general, the "main" exchange of the area serves the business and shopping centre of the town, whilst the satellite exchanges serve the various residential suburbs. There is a certain amount of local traffic in each suburb, but by far the greatest proportion of the traffic is from the satellite exchanges to the main business centre. In some cases, there is comparatively little traffic between the various satellite exchanges. In other cases, e.g. where, say, a common shopping centre serves two adjacent satellite areas, there may be a certain amount of traffic between these two adjacent satellite exchanges. Generally speaking, however, this traffic is very small compared with the traffic on the satellite-to-main routes.

It would be possible to design a switching scheme so that all the satellite exchanges were linked together and to the main exchange by means of separate junction routes as in Fig. 363. In most cases the satellite-to-satellite routes would carry very little traffic, and the resultant small groups of junctions would be worked comparatively uneconomically. There are very few

multi-exchange areas where there is sufficient satellite-to-satellite traffic to justify more than one or two direct routes between adjacent exchanges. Hence the standard automatic system designed for use in a multi-exchange area is based on the principle that the main exchange is used as a tandem switching centre for most of the satellite-to-satellite traffic (Fig. 364). By adopting this trunking scheme it is possible to provide large groups of junctions between each satellite exchange and the main exchange with the consequent high degree of efficiency both on the junction pairs and on the automatic selectors which terminate the junctions. The use of the main exchange as a tandem switching point does not, of course, preclude the use of a direct route between certain satellites if this can be justified on economic grounds.

Simple Satellite Scheme. Fig. 365 shows a simple trunking scheme for an exchange area consisting of a main exchange and two satellite exchanges, East and West. It is assumed that the main exchange has to provide for a maximum of 2000 lines, whilst West satellite caters for a group of 1600 lines on the outskirts of the town. East satellite exchange is assumed to be smaller and provides for a maximum of 400 subscribers. A common numbering scheme is applied to the whole area, so that the subscribers on the several

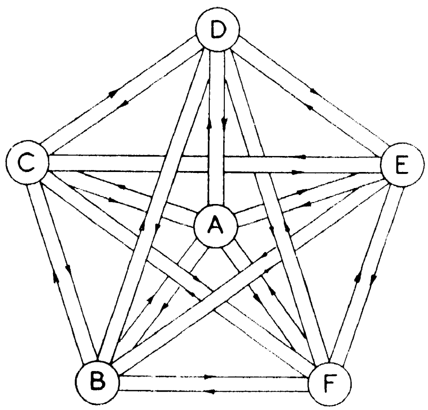


FIG. 363. MULTI-EXCHANGE AREA WITH DIRECT ROUTES BETWEEN EXCHANGES

exchanges have numbers within the following groups:

Main Exchange . . .	2000–3999
East Satellite . . .	4200–4599
West Satellite . . .	5000–5999 6200–6799

The trunking arrangements are such that whenever a subscriber lifts his receiver his uniselector extends his line to a 1st selector in the main exchange. The connexions between the main exchange subscribers' uniselectors and the 1st selectors are formed by the local wiring between the respective racks, but the outlets from the

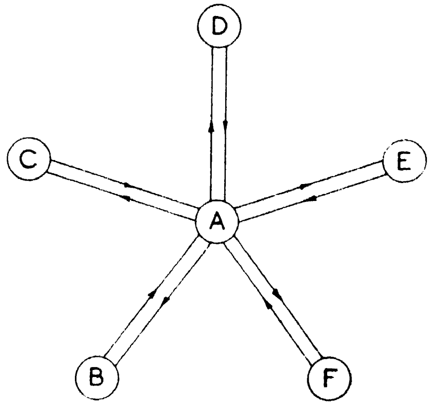


FIG. 364. MULTI-EXCHANGE AREA WITH MAIN EXCHANGE SERVING AS TANDEM SWITCHING POINT FOR SATELLITE-TO-SATELLITE TRAFFIC

satellite exchange uniselectors have to be extended over 2-wire junctions to reach the 1st selectors at the main exchange. It is, of course, necessary to provide a holding circuit for the uniselector at the originating exchange, and this necessitates the insertion of auto-auto relay sets on each outgoing junction from the satellite exchanges.

The outgoing junctions from the main to the satellite exchanges are connected to suitable levels of the group selectors in the main exchange. Thus, by allocating a 1st selector level to an outgoing satellite exchange group, and by providing 2nd and final selectors at the satellite exchange itself, it is readily possible to provide for a number of satellite exchanges. In Fig. 365 two 1st selector levels (i.e. 5 and 6) are required to serve the West satellite, since the capacity of this exchange is in excess of 1000 lines. In some cases it may be uneconomical to allocate a 1st selector level to a small satellite exchange, and in such circumstances it may be preferable to serve the outgoing junctions to a small satellite from a level of 2nd selectors at the main exchange.

The capacity of the system can be increased by the adoption of a 5-digit numbering scheme. In this case each 1st selector level can be used to give access to a maximum of 10 000 lines, and each 2nd selector level can be used to serve a satellite exchange of up to 1000 lines.

Outgoing auto-auto relay sets are required on all outgoing routes from the main exchange to the

satellite exchanges for the purpose of providing the necessary holding conditions for the main exchange train of selectors. If required, the 1st selectors at the main exchange can be arranged as separate groups serving the various satellite exchanges and main exchange. By sub-dividing the 1st selectors into a number of such groups, it is possible to provide separate circuits from each exchange to such points as the automanual board, the various service levels, etc.

It will be noted that six of the levels of 2nd selectors at East satellite are spare and may not be required to meet development at this exchange. In the same way there are four spare levels on the 2nd selectors of the No. 6 group at West satellite exchange. The spare 2nd selector levels could be made available for subscribers at the main exchange if these particular groups of 2nd selectors were located in the main exchange instead of at the satellite. This would mean, however, that separate groups of junctions from the main exchange to each satellite would have to be provided for each of the 2nd selector levels required by the satellite numbering scheme. The consequent sub-division of the junctions would reduce their traffic carrying capacity but, since there is no sub-division of the final selectors in each group, the average traffic loading of these selectors would not be changed.

There are two main disadvantages with the simple satellite scheme illustrated in Fig. 365. The trunking scheme is such that all calls from a satellite exchange must be routed through the main exchange equipment. This is quite satisfactory for the high percentage of satellite-to-main calls, and also for calls to other satellite exchanges where there is a small community of interest. The same routing must, however, be followed on a purely local call, i.e. from one subscriber to another subscriber on the same satellite exchange. In such cases the use of two junctions (an outgoing and an incoming) and the occupancy of the main exchange selectors is somewhat wasteful and could be avoided if some means of direct access could be provided within the local satellite exchange. The disadvantage may not be intolerable in a small exchange where there is comparatively little local traffic, but it can represent a serious loss of efficiency in a satellite exchange of several thousand lines where there is an appreciable number of local calls. The trunking scheme of Fig. 365 does not, moreover, provide facilities for the exceptional case where a direct route between two satellite exchanges is justified.

A further difficulty of the simple scheme so far considered is the necessity for providing a large group of high-grade junctions between each satellite exchange and the main exchange. When the calling subscriber wishes to originate a trunk call, his uniselector hunts for and seizes a free junction to the main exchange in exactly the same way as when a local call is required. The junctions

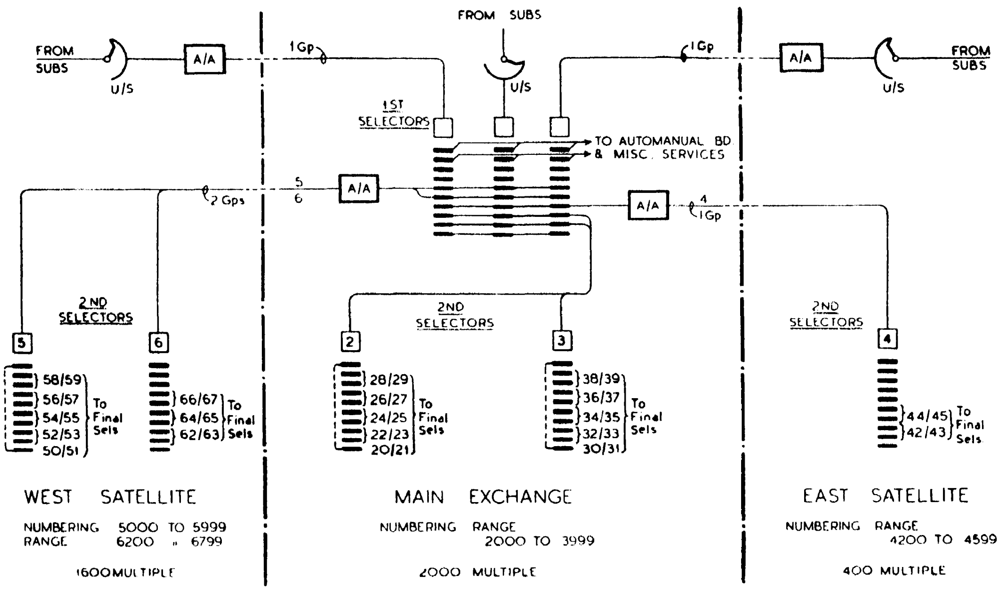


FIG. 365. SIMPLE SATELLITE TRUNKING SCHEME

necessary for local traffic can be of a much lower standard than the junctions required for carrying trunk traffic. Since, however, both classes of traffic are mixed indiscriminately on the satellite-to-main junction routes, it becomes necessary to make *all* the junctions of the high standard dictated by the requirements of long-distance trunk calls. It would be a considerable improvement if a scheme could be developed to provide a group of junctions to the main exchange for traffic within the linked numbering scheme and a separate and smaller group of junctions to the 10th level of the 1st selector over a special group of high-grade circuits to the trunk switchboard.

Calls to the main exchange are determined by the dialling of the initial digits 2 or 3. The trunks from these levels of the 1st selector are routed via auto-auto relay sets to the appropriate group of 2nd selectors at the main exchange. If the call is destined for the East satellite exchange, a caller on West dials "4" to seize a 2nd selector at the East satellite, and on dialling the second digit 2, 3, 4, or 5 he is extended to a final selector.

A subscriber on East satellite exchange is routed in a similar manner, either locally or through the main exchange 2nd selectors.

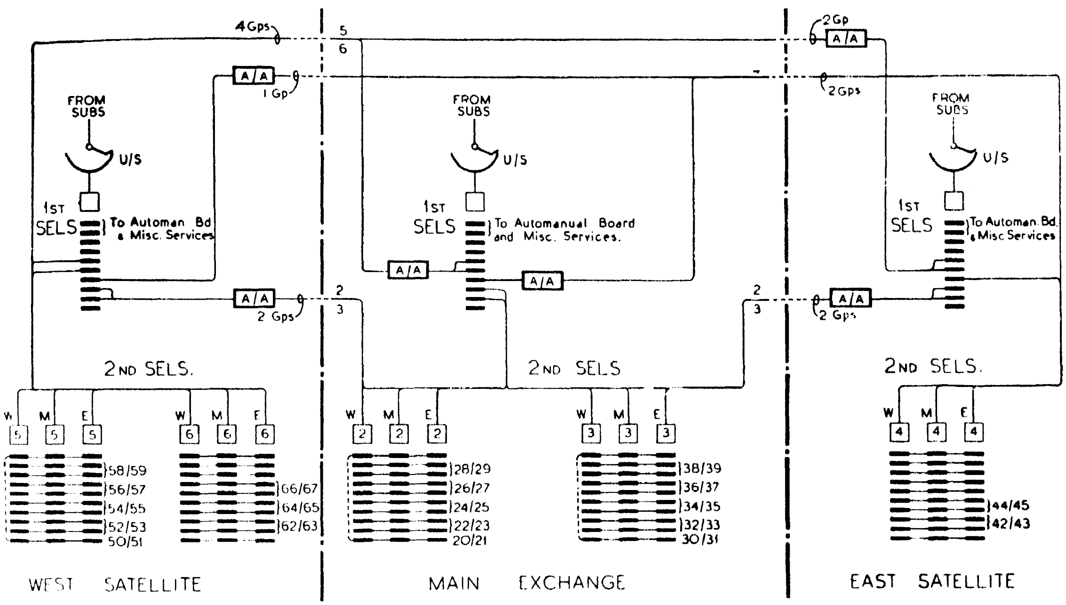


FIG. 366. SATELLITE SCHEME WITH DIRECT LOCAL SWITCHING

automanual board for the completion of long-distance trunk calls.

Direct Local Switching. The two requirements of direct switching on local satellite calls, and separate access to the trunk demand operator, could be obtained by a trunking scheme on the lines of Fig. 366. First selectors are now provided at each satellite exchange, and the levels of these selectors are trunked to the appropriate 2nd selectors either locally or in the main exchange. Thus, a subscriber on West exchange is extended by his uniselector to a local 1st selector from which he receives dial tone. If the initial digit is 5 or 6, the call is routed to a local 2nd selector, and subsequent digits extend the call to a final selector. No junctions and no selectors in the main exchange are occupied for such a local call. Similarly, if the calling subscriber dials "0" to obtain the automanual operator, he is extended from the

The defects of this trunking scheme are clear. Whereas under the original scheme it was possible to provide one large common group of junctions between each satellite and the main exchange, the new trunking scheme involves the provision of a number of separate groups of junctions between the satellite exchange 1st selector levels and the appropriate groups of 2nd selectors at the main exchange. Moreover, direct junctions are now required between the West and East satellite exchanges although the community of interest may be very small indeed. This segregation of the traffic into a number of separate and smaller groups materially degrades the trunking efficiency.

There are very few cases where the adoption of a simple switching scheme on the lines of Fig. 366 would be tolerable on economic grounds.

Discriminating Satellite Scheme. *The solution to the problem lies in the provision of* equipment at the satellite exchanges which will:

(*a*) permit the establishment of local calls (*i.e.* within the particular satellite exchange) without the use of junctions to the main exchange, or equipment at the main exchange;

(*b*) provide facilities for the direct routing of calls between satellite exchanges (when such direct routes are justified) without engaging selectors at the main exchange;

(*c*) provide a separate group of high-grade junctions (distinct from the local junction network) for outgoing trunk traffic;

(*d*) provide for the completion of all other calls (e.g. to subscribers on the main exchange and to indirectly connected satellites) by the use of a common group of circuits from the satellite to the main exchange.

All the above requirements can be resolved into two basic switching conditions. The equipment at the satellite exchange must either route the call over a common group of junctions to a 1st selector at the main exchange or, alternatively, switch the call over a direct circuit to the required destination, i.e. to the manual board, to the local 2nd selectors, or to an adjacent satellite. The discrimination between the two types of call must be determined from the digits dialled by the calling subscriber but the destination of the call may not be fully determined until one, two, or perhaps even three digits have been dialled. One method would be to store the impulse trains until the equipment could discriminate, and then re-transmit the impulse trains to step either the central exchange selectors or the local selectors, *as determined by the discrimination. As an alternative to storing the impulse trains until* discrimination is effected, arrangements could be made so that both the main exchange selectors and the local selectors are stepped in parallel until sufficient digits have been received to permit discrimination. The unwanted chain of selectors could then be released and the call fully established over the selected route. Most of the discriminating satellite exchanges in service are of the latter type, although the latest standard equipment makes use of the impulse storage principle.

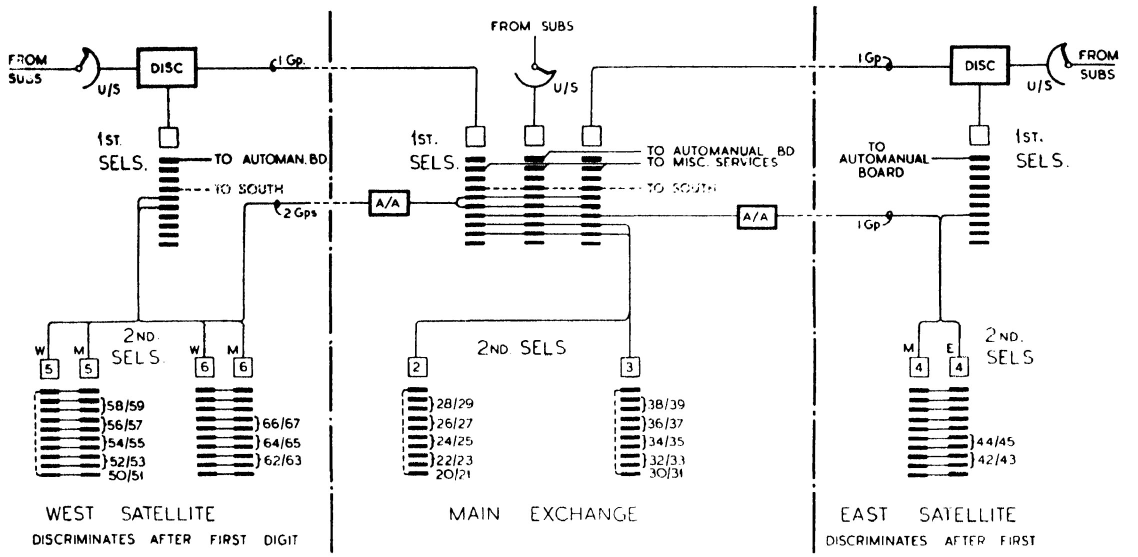


FIG. 367. SATELLITE SCHEME WITH DISCRIMINATION FACILITIES

Fig. 367 shows the principle of satellite working with discriminating facilities, but without impulse storage. The same numbering scheme as Figs. 365 and 366 has been retained to facilitate comparison. When a subscriber on, say, West satellite exchange lifts his receiver to make a call, his uniselector seizes a discrimination circuit with which is associated a local 1st selector and a junction to the main exchange. The extension of the calling subscriber's loop seizes the satellite 1st selector and also the main exchange 1st selector. The first impulse train causes the satellite and main exchange 1st selectors to step in unison, and also actuates an impulse counting mechanism in the discriminating circuit. If the call is local, the called subscriber's number will commence with either 5 or 6, and at the end of the first impulse train the discriminating circuit is arranged to

release the junction to the main exchange and to switch the call so that all subsequent digits are routed to the local selectors.

If, on the other hand, the initial digit is 2, 3, or 4, it indicates that the call is to be routed via the main exchange. On receipt of such a digit, the discriminating circuit releases the satellite 1st selector and switches all subsequent impulse trains over the junction to the main exchange. If digit 0 is dialled, then the discriminating circuit is arranged to release the main exchange junction and to switch the call to the trunk operator via the "0" level of the satellite 1st selector.

Similar facilities can be provided at the East satellite exchange. In this case, however, the discriminating circuit determines that the call is local when an initial digit 4 is dialled.

In some circumstances, the trunking arrangements may be such that it is not possible to discriminate until after the second, or perhaps even the third digit, has been received, but the discrimination circuit can be designed to give these facilities if required. The circuit does, of course, become more complex and costly as the facilities are increased.

The same circuit features also permit the provision of direct routes between satellite exchanges if in any particular circumstances there is a sufficiently high volume of traffic to justify such a provision. If, for example, there were a third satellite exchange (South) with the numbering range 7000–7999, a direct route could be provided from West to South from the 7th level of the West satellite 1st selectors. In this case the discriminating circuit would arrange to drop the junction to the main exchange on receipt of an initial digit 7, and switch the call via the local 1st selector. If necessary, a direct route could be provided from a 2nd or subsequent selector, but local discrimination would then have to await receipt of the second or third digit.

Digit Absorption. One further refinement to the trunking scheme of Fig. 367 is possible. In some cases the levels of the local selectors at the satellite exchanges are not utilized to the best advantage. This is particularly so at the East satellite of Fig. 367. In this instance only two levels of the 1st selectors are used for traffic, and only four levels of the local group of 2nd selectors are in use. The 1st selector in fact merely differentiates between "0" level traffic and local traffic, and the 2nd selector determines the correct one of 4 final selector groups. There is no fundamental reason, however, why the final selectors should not be connected direct to the spare levels of the 1st selector, thereby completely eliminating the 2nd group selectors. This trunking economy could be obtained if the 1st selector at the satellite exchange (or the associated discriminating circuit) could be arranged to absorb the first digit on a purely local call.

Three levels of the 1st selectors at West satellite are in use but, since the size of this exchange necessitates 16 2nd selector levels, it is not possible to eliminate the 2nd selectors in their entirety. It is, however, possible to cut out one of the two groups of 2nd selectors by accommodating as many as possible of the final selector groups on the spare 1st selector levels. Thus if level 5 2nd selectors are retained to give access to ten groups of final selectors, it is possible to accommodate the remaining six groups of final selectors on six of the spare levels of the 1st selectors. This will necessitate some slight amendment to the numbering scheme owing to the fact that levels 5 and 0 are already occupied. A suitable numbering scheme for the West satellite under these conditions would then be:

5000–5999
6100–6499
6800–6999

This will leave levels 6 and 7 spare for future development. If, however, level 7 is required for a direct route to an adjacent satellite, then the ultimate 67 final selector group is no longer possible.

The above facilities can readily be obtained by arranging for the absorption of the first digit 6 on local calls. Thus, if a subscriber on West satellite dials a local number, say 6234, the satellite 1st selector steps to the 6th level in response to the first digit, but restores to normal during the interdigital pause before the second digit. The second digit (2) steps the 1st selector to the 2nd level, and the call is then extended to the 62 final selector group where the two final digits complete the connexion to the required subscriber.

Fig. 368 shows the same trunking arrangement as Fig. 367 but with digit absorption. The simplified trunking arrangements and the economy in selectors are clear.

Fig. 368 also shows a somewhat different arrangement of the discriminating equipment. We have seen that the discriminating circuit is required to count the first impulse train dialled by the calling subscriber. The 1st selector itself can be used as an impulse counting circuit by providing either a vertical marking bank or for the wipers to cut into the first contact of the bank at the end of the first digit. Relays can be provided in the 1st selector circuit to apply suitable marking

conditions to the 1st selector bank, so that local or junction discrimination can be given as desired depending upon the value of the initial digit. In the past, therefore, it has been usual to combine the discriminating circuit with the 1st selector —the whole being known as a *discriminating selector*. It will also be noted that a uniselector has been inserted between the 1st selector and the junctions to the main exchange. The provision of one junction for each satellite 1st selector (or discriminating selector) is somewhat wasteful, since this junction would be unavailable for traffic whilst the discriminating selector is in use on a local call. The provision of a *junction hunter* uniselector enables all the junctions to the main exchange to be placed in a common pool, which is accessible to all discriminating selectors when a call via the main exchange is required.

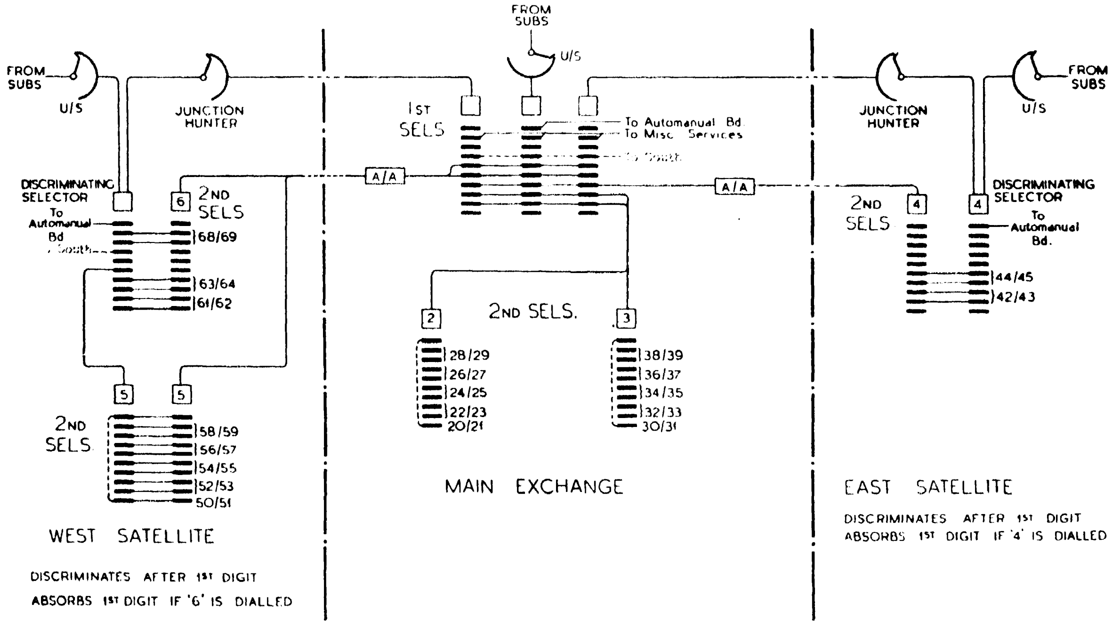


FIG. 368. SATELLITE TRUNKING SCHEME WITH DISCRIMINATION AND DIGIT ABSORPTION

Mixed 4- and 5-digit Areas. The number of exchanges in a multi-exchange scheme may be such that the levels required for routing calls between exchanges do not leave sufficient multiple capacity for the adoption of a 4-digit scheme. On the other hand, the adoption of a full 5-digit numbering range for all subscribers in the area may be uneconomical. In these circumstances a mixed 4- and 5-digit numbering scheme has often been adopted in the past to provide the necessary multiple capacity, but at the same time to economize as much as possible in the quantity of intermediate selectors. Generally speaking, it is best to reserve the 4-digit numbers for the main exchange subscribers (where there are no digit absorption facilities), and to allocate 5-digit numbers to the lines on the satellite exchanges. In some cases the most economical arrangement may involve the use of both 4- and 5-digit numbers in the same satellite exchange. It is often possible to open an area with a 4-digit numbering scheme or with the bulk of subscribers on a 4-digit basis, and then gradually to extend the number of 5-digit subscribers as the system grows.

An exchange area with a linked numbering scheme containing subscribers' lines of varying numbers of digits tends to complicate the procedure on long-distance dialling. It has therefore been decided that in future mixed digit areas will be avoided in order to prevent possible complications to the development of long-distance dialling.

More Complex Discrimination and Absorption Facilities. Fig. 369 shows a discriminating satellite exchange trunking scheme in an area with a more or less complex numbering scheme. Five-digit numbers are used throughout and are allocated to the various exchanges in the area as follows:

Satellite A (1700 multiple) . .	71 100–71 199
	71 400–71 999
	72 000–72 999
Satellite B (1000 multiple) . .	73 000–73 999
Main Exchange and other Satellites	20 000–70 999
	74 000–89 999

A direct route is required between satellite *A* and satellite *B*, and a direct group of "0" level circuits is required from satellite *A* to the trunk demand switchboard. All other calls are to be routed via the levels of the group selectors at the main exchange.

The most economical use of the discriminating selector banks at satellite *A* can be made with the following level allocations:

Level 0: to automanual board
Level 9: to final selector group 719**
Level 8: to final selector group 718**
Level 7: to final selector group 717**
Level 6: to final selector group 716**
Level 5: to final selector group 715**
Level 4: to final selector group 714**
Level 3: to 3rd selectors at satellite *B*
Level 2: to local 3rd selectors serving final selector groups 720** to 729**
Level 1: to final selector group 711**

With this arrangement, the discriminating selector is required to:

(*a*) give local discrimination without digit absorption when "0" is dialled;

(*b*) absorb a first digit of 7 and to give local discrimination when the second digit is 2 or 3;

(*c*) absorb the first two digits if they are 7 and 1 respectively, and to give local discrimination when the third digit is 1, 4, 5, 6, 7, 8, or 9;

(*d*) give junction discrimination for all other combinations of digits.

The requirements can be scheduled in tabular form:

Number Dialled	1st Digit	2nd Digit	3rd Digit
0	LD	JD	JD
9	JD	JD	LD
8	JD	JD	LD
7	A	JD	LD
6	JD	JD	LD
5	JD	JD	LD
4	JD	JD	LD
3	JD	LD	JD
2	JD	LD	JD
1	JD	A	LD

A = digit absorbed.
JD = junction discrimination.
LD = local discrimination.

Differentiation and switching to meet the various conditions can be provided by a number of relays controlled from the electrical conditions on the various levels of a vertical marking bank or from the first contact of each level of an additional line bank. The latter scheme is employed in the standard discriminating selector. It is clear from the above tabulation, however, that the conditions required on any one level often differ for each digit. On level 7, for example, the marking of the bank must be such that the selector releases if "7" is dialled as the *first* digit, whilst if the "7" is a *second* digit the selector must switch for a junction call, and finally if "7" is dialled as the *third* digit the wipers must drive

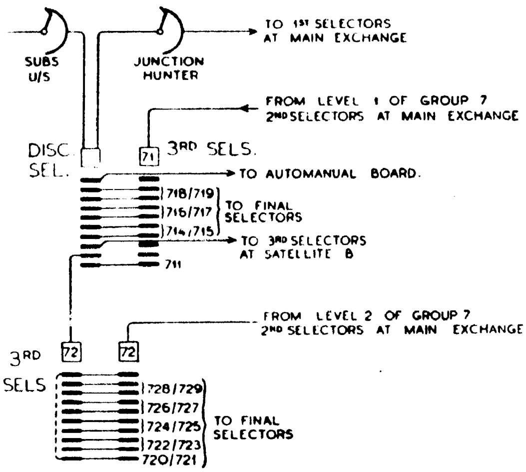


FIG. 369. A MORE COMPLEX SATELLITE TRUNKING SCHEME
(Satellite *A*)

round the bank to seize a local final selector. It is this change of conditions for each successive digit which complicates the switching arrangements of a discriminating selector.

Discrimination Circuit. The discrimination and digit absorbing elements of a discriminating selector circuit are given in Fig. 370. The circuit as shown provides for the absorption of one or two digits and for discrimination after the first, second, or third digit. There are 6 controlling relays, viz:

DA: releases selector to absorb 1st digit.
OA: re-arranges conditions on marking bank levels when selector returns to normal after absorption of 1st digit.
DB: releases selector to absorb 2nd digit.
OB: re-arranges conditions on marking bank levels when selector returns to normal after absorption of 2nd digit.
JD: discriminates for a junction call via the main exchange.

LD: discriminates for a local call via the selector banks. (Local discrimination is required for "0" level calls and adjacent exchange calls as well as for local calls.)

Relays *JD* and *LD* are connected via various combinations of *OA* and *OB* contacts to the selector shelf jack where they are commoned as required to other jack springs wired to the first contacts of each *P*1 bank level. Jack point *D*, for example, is

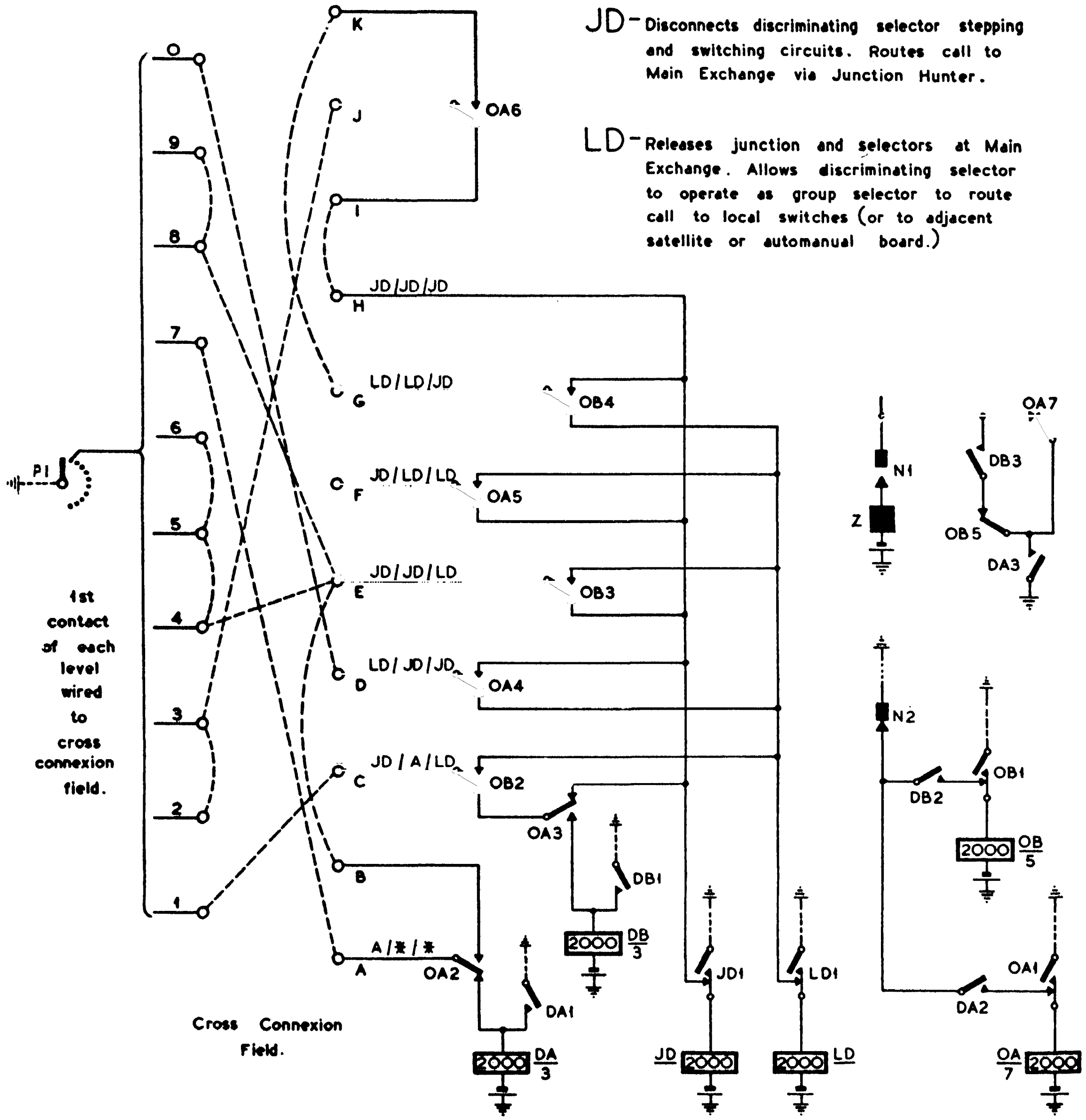


FIG. 370. DISCRIMINATION CIRCUIT

In the practical circuit described later, relays *DA* and *DB* take over some of the functions of *OA* and *OB* to reduce the spring load of the latter. *OA* and *OB* must be provided, however, since in some cases the discriminating conditions cannot be arranged until the wipers are clear of the marking bank contact.

connected via *OA*4 so that an earth will operate *LD* on the first digit but will operate *JD* if the earth is applied at the second or third digit. Other common combinations are provided by leads *C* to *H*, but it is obviously impracticable to have a separate lead for every possible permutation of digit absorption, junction discrimination and

local discrimination. The requirements of uncommon combinations are therefore provided by contacts $OA2$ and $OA6$ which enable any level to be connected to one discriminating lead for the first digit and then switched to another lead for the second and subsequent digits.

The cross-connexions shown in Fig. 370 relate to the numbering scheme assumed in the previous paragraph (Fig. 369) and represent fairly complex conditions. In a number of cases, a simpler system of cross-connexions will suffice.

When the subscriber dials the first digit, the wipers are stepped up to the appropriate level and the selector makes one rotary step. An earth applied to the $P1$ wiper is extended via the cross-connexion field to the appropriate discriminating relay. If the initial digit is other than 7 or 0, relay JD is operated and locks to its own contact. The remaining contacts of JD prevent any further stepping or switching of the discriminating selector and all subsequent impulse trains are repeated to the main exchange.

If the initial digit is 0, relay LD is operated via terminal D and contact $OA4$. LD locks at ***LD*1**, and other contacts of this relay release the junction and the first selector at the main exchange. The remaining contacts of LD cause the discriminating selector to hunt over the "0" level and to seize a junction to the automanual board.

An initial digit of 7 applies earth from $P1$ to terminal A and thence via $OA2$ to operate relay DA. DA locks to ***DA*1** whilst ***DA*3** energizes the release magnet. When the wiper shaft is fully restored, the Z magnet circuit is broken at $N1$, whilst $N2$ operates relay OA via ***DA*2**. ***OA*1** provides a holding circuit for OA, and ***OA*7** prevents premature release when the 2nd digit is received. Contacts ***OA*2** to ***OA*6** change over the conditions on the A, D, F, and J leads.

If the second digit is 2 or 3, the $P1$ earth is extended to operate relay LD (via J, K, and G) and so to effect local discrimination. Second digits of 4, 5, 6, 8, or 9 operate relay JD via terminal E to give junction discrimination, and similarly second digits of 7 or 0 operate JD via terminals A, B, E, and D respectively.

If the second digit is 1, the $P1$ earth is extended via terminal C, $OB2$ and ***OA*3** to operate relay DB. DB locks to ***DB*1**, and ***DB*3** energizes the release magnet. When the selector restores, $N1$ breaks the release magnet circuit and $N2$ operates OB via ***DB*2**. OB now locks and at ***OB*5** prevents false operation of the release magnet on the third digit, whilst contacts ***OB*2**, ***OB*3**, and ***OB*4** switch the conditions on the C, E, and G leads respectively. The circuit does not provide for any further absorption of digits and, when the third digit is received, the earth on $P1$ operates either JD or LD to determine the routing of the call.

Discriminating Selector Circuit. A typical discriminating selector circuit is given in Fig. 371. It provides facilities for discriminating on receipt of the first, second, or third digit as required and can be arranged to absorb either the first or the first two digits. The circuit is of the pre-2000 type, and the main stepping and switching elements are as already considered in Chapters V to X.

When the selector is seized, relays A, B, and MD operate. ***MD*2** completes the drive circuit of the junction hunter uniselector, and, when a free junction is found, relay K operates. ***K*5** connects dial tone to the caller whilst ***K*6** and ***K*7** extend the D and I loop to seize the 1st selector at the main exchange. Relay I operates to the junction loop current, and the circuit is now ready to receive the first impulse train.

Calls via Main Exchange. In Fig. 371 it is assumed that initial digits of 1, 2, 3, 4, 5, 6, 8, or 9 determine that the routing of the call is via the main exchange. Relay A responds to the dialled impulses, and, at the first break, $A1$ operates relays C and JG. ***C*2** short-circuits relays D and I and completes the impulsing loop to the main exchange. JG locks at ***JG*1** until discrimination is effected, and ***JG*2** operates relay J in readiness for metering. The impulse train is passed to the vertical magnet via ***MD*3**, $H1$, and $JD1$, and, as the switch moves off-normal, contacts ***N*2** complete the circuit for G which operates in readiness for rotary stepping. At the end of the impulse train, relay C releases. It will be noted that C is in parallel with the V magnet instead of the more usual series arrangement. This change is necessary to enable C to be operated independently of the magnet after junction discrimination. The rectifier MRB minimizes the slugging effect of relay C on the magnet.

$C1$, in releasing, completes the rotary drive circuit, and the wipers are stepped to the first contact of the bank. ***R*1** now breaks the circuit of G, and $G2$, in turn, disconnects the R magnet. If a main exchange level has been dialled, relay JD now operates from the earth at ***K*4** via ***JG*4**, the $P1$ bank and the cross-connexion field. ***JD*1** disconnects the V magnet circuit, ***JD*2** releases JG whilst ***JD*3** disconnects the G relay circuit and prepares a holding circuit for K. ***JD*2** provides a hold circuit for JD.

The subscriber now dials the second and subsequent digits which are repeated at $A2$ to the main exchange selectors. The local discriminating

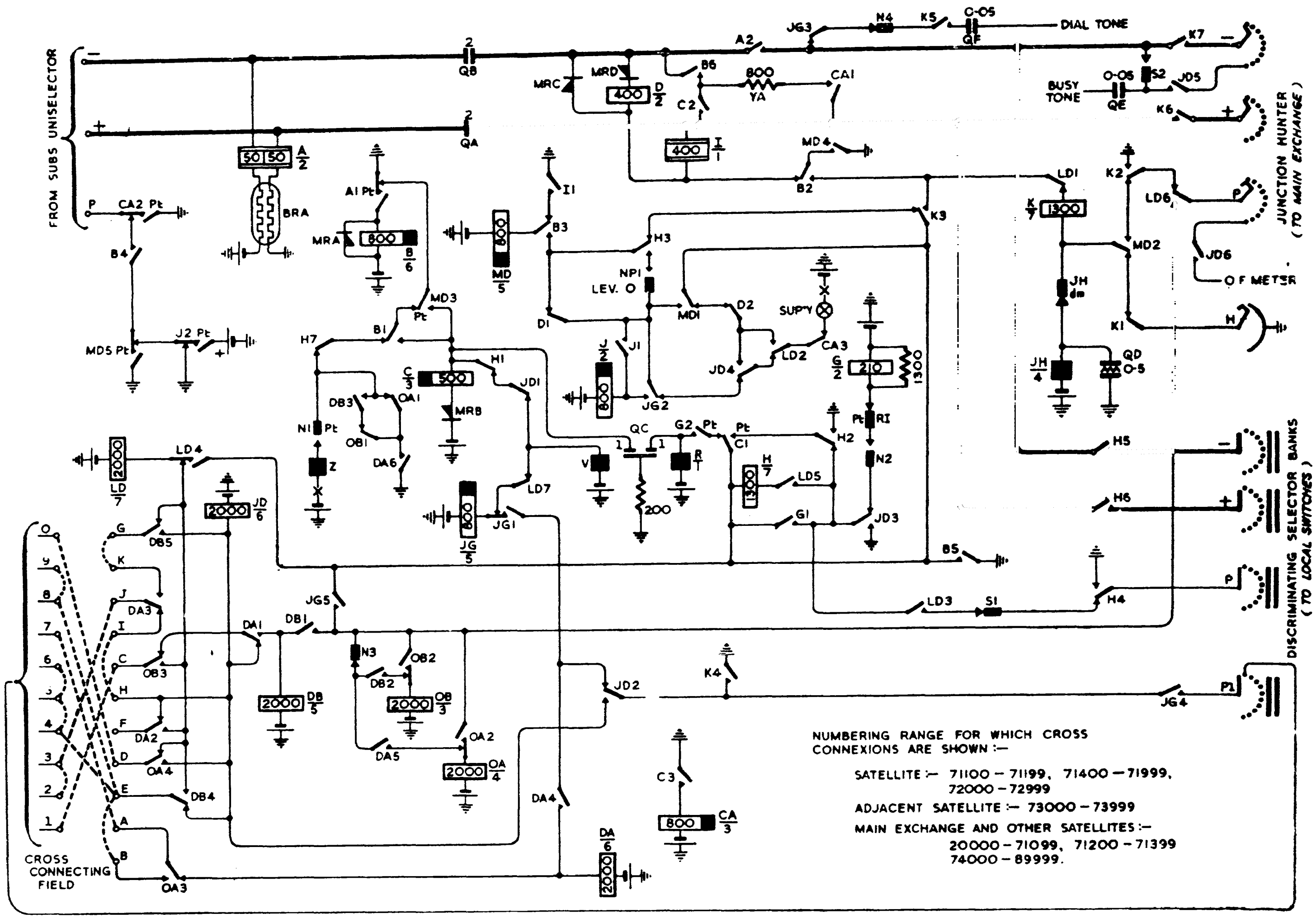


Fig. 371. Discriminating Selector Circuit (Pre-2000 Type)

selector cannot respond to these digits due to the break at ***JD*1**, and the wipers remain on the first contact of the initial level. (It should be noted that the outlet is not engaged by the selector and the wipers are disconnected at *LD*3, *H*5, *H*6, and *JG*4.)

When the called subscriber answers, relay *D* operates to the reversal of potential from the final selector. ***D*1** disconnects *MD* which at *MD*1 breaks the circuit of *J*. A positive battery metering pulse is applied to the *P*-wire for the release lag of *J* (contacts *MD*5 and ***J*2**). At the end of the call, the calling subscriber releases relay *A*. *A*1 releases *B* and energizes *C* during the release lag of ***B*1**. *A*2 releases the main exchange selectors. A guarding earth is applied to the *P*-wire by ***CA*2** to cover the release lags of the various relays (*D*, *I*, *B*, *C*, *CA*, *K*, and *JD*).

Local Calls and Calls to Adjacent Exchanges. The digit absorbing and discrimination arrangements for local calls are determined by the local trunking scheme. Assume as in Fig. 369 that part of the local numbering range is 71 400 to 71 999. Under these conditions, the first two digits are absorbed and the selector discriminates on the third digit to route the call direct to local final selectors. On receipt of the first digit (7), relay *DA* operates from the earth at ***K*4** via ***JG*4**, *P*1 bank, the cross-connexion field and *OA*3. ***DA*1**, ***DA*2**, and ***DA*3** re-arrange the cross-connexions in readiness for the next digit whilst ***DA*4** provides a holding circuit for *DA*. ***DA*6** completes the release magnet circuit, and the mechanism restores to normal. At the end of vertical release, *N*1 breaks the *Z* magnet circuit, and *N*3 operates *OA* via ***DA*5**. *OA* now holds via ***OA*2** and at ***OA*3** and ***OA*4** further re-arranges the cross-connexions.

When the second digit (1) is dialled, *DB* operates from the *P*1 bank via *OB*3 and ***DA*1**. *DB* holds at ***DB*1** and again completes the release magnet circuit at ***DB*3**. ***DB*5** and ***DB*4** switch the connexions of the *P*1 bank. The selector returns to normal, and, at the end of the release movement, *N*3 operates relay *OB* via contact ***DB*2**. *OB* locks at ***OB*2** whilst ***OB*3** carries out further switching of the *P*1 bank connexions.

On receipt of the third digit, relay *LD* operates from the *P*1 earth over the circuit prepared at *DB*4 and ***OA*3**. ***LD*1** breaks the holding circuit of the *K* relay and thereby releases the junction to the main exchange. *K*4 releases *JG* and *DA*, and *JG*5 in turn releases *DB*, *OA*, and *OB*. The automatic rotary drive circuit is completed at ***LD*3** and the *H* relay switching circuit is prepared at ***LD*5**. ***LD*4** provides a hold circuit for *LD*, whilst ***LD*7** prevents the re-operation of *JG* on subsequent impulse trains.

When a free outlet is found, relay *H* operates and at ***H*4**, ***H*5**, and ***H*6** switches the impulsing loop and speaking circuit to the local final selector. The supervisory, metering, and release conditions are similar to those of a junction call.

If local subscribers are obtained via final selectors connected to the banks of an intermediate group selector (subscribers 72 000–72 999), the discriminating selector is required to absorb the first digit and to effect discrimination at the end of the second digit. Under these conditions, the *P*1 bank cross-connexions are arranged so that the first digit operates relays *DA* and *OA* whilst the second digit operates relay *LD*. Similar arrangements are required on calls to an adjacent automatic exchange when the trunking arrangements require two digits to reach the junction route. Calls to an adjacent exchange are routed from a level of the discriminating selector, and hence the circuit must be arranged for *local* discrimination and not junction discrimination.

"0" *Level Calls.* As previously explained, it is usual to provide direct circuits of high grade from each satellite to the manual board. The junctions are trunked from the 10th level of the discriminating selector, and the circuit is arranged to give *local* discrimination when "0" is dialled. Metering is not required on manual board calls but operator hold conditions are substituted.

Normal post springs ***NP*1** close when the wipers are stepped to the "0" level, and provide a hold circuit for *MD* independent of *D*1. The first *P*1 contact on the "0" level is strapped to operate relay *LD* via *OA*4. The selector therefore switches to extend the caller to the manual board via the "0" level of the discriminating selector.

When the calling subscriber replaces his receiver, relays *A* and *B* release. *A*2 disconnects the loop to give a clear to the operator and relays *D* and *I* also release. *A*1 operates *C* and **C1** completes an alternative holding circuit for *J*, *H*, and *LD*. **C3** operates *CA* and ***CA*2** maintains the earth on the *P*-wire. On the release of *B*, *B*2 provides an operate circuit for *I* to the battery on the positive wire from the manual board. ***I*1** holds *MD* and ***MD*3** in turn holds *C* and *CA*. ***CA*2** maintains a holding earth on the *P*-wire until such time as the operator clears down and releases *I*.

Junction Guard Relays. When the discriminating selector circuit switches for a local call, relay *K* of the junction hunter circuit is disconnected at ***LD*1** (Fig. 371). *K* releases quickly and the holding loop for the selectors at the main exchange is broken at *K*6 and *K*7. At the same time *K*2 removes the guarding earth from the *P* bank of the junction hunter. It is clear, therefore, that

the junction can be re-seized by another discriminating selector from the moment that $K2$ releases. The selectors at the main exchange do not, however, commence to release until the B relay of the most forward switch is fully restored. This produces an unguarded period of some 300–400 msec during which the selector train at the main exchange can be re-seized. As a safeguard, two relays per junction are connected to the P bank of the junction hunter to prolong the guarding earth for some 400 msec after the release of K. Fig. 372 shows the arrangement. Relay JA is operated from the P bank via $JB1$ when the junction is seized. **$JA2$** provides a holding circuit for JA independent of $JB1$ whilst **$JA3$** operates

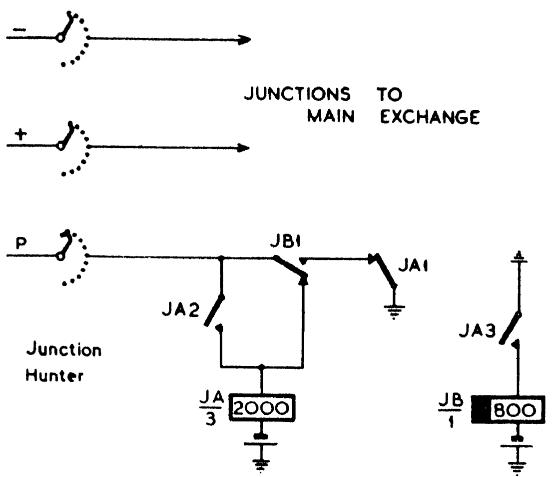


Fig. 372. Junction Guard Relays

relay JB. When the junction is released from the discriminating selector, JA releases but on the release of $JA1$ an earth is re-applied to the P-wire for the release lag period of relay JB.

Satellite Exchanges with Multi-metering Facilities. The extension of dialling and the consequent introduction of multi-metering in non-director areas necessitate the provision of additional equipment at any satellite exchanges in the area. The normal pre-2000 type discriminating selector (e.g. Fig. 371) provides for—

(*a*) Discrimination between local calls and calls which are to be routed via the main exchange.

(*b*) The absorption of digits on local calls in order to effect savings in the number of selectors required at the satellite exchange.

These normal discrimination and absorption features require a number of relays, and hence the discriminating selector is comparatively complex and costly. The addition of multi-metering equipment to such a selector still further increases the complexity of the circuit. The relays introduced for discrimination, digit absorption, fee determination, route restriction, etc., are not required once the call has been established. It is possible, therefore, that economies can be obtained by divorcing these elements from the discriminating selector and placing them in common circuits which can be associated with the 1st selectors during the setting up of a call. The introduction of the 2000 type selector provided an excellent opportunity to examine the possibilities in this direction.

There are certain other factors which should be borne in mind in the design of the circuits at a discriminating satellite exchange. The normal design of the discriminating selector provides for the seizure (via a junction hunter) of a 1st selector at the main exchange immediately the call is initiated. This selector is stepped "in parallel" with the discriminating selector at the satellite exchange until such time as discrimination is effected. At this point either the local selectors or the main exchange train of switches are released, depending on whether or not local discrimination is required. This feature introduces artificial traffic on the satellite-to-main-exchange junction route, and on the first and subsequent selectors at the main exchange. Moreover, the repeated seizure and release of the main exchange selectors increases the wear and also the amount of maintenance attention necessary. It is preferable that the junction to the main exchange is not seized until the local discriminating circuit has determined that the call is proper to be routed via the main exchange. Normally it is not possible to determine whether a call is local until after the receipt of the first, second, or even third digit. Hence, if the initial seizure of the main exchange junction, etc., is to be avoided, it becomes necessary to introduce some form of impulse storage and regeneration at the satellite exchange.

The discrimination circuit of the pre-2000 type discriminating selector is somewhat complicated due to the fact that the discriminating condition is applied to the 1st contacts of the $P1$ bank. The use of this single 10-point marking system requires that there should be a system of altering the conditions on the marking bank after each successive digit in order that second and third digit discrimination can be made possible. The discrimination circuit can be simplified if the impulse counting system required for fee determination can also be used to provide discrimination facilities.

Again, on pre-2000 type discriminating selectors, digit absorption is obtained by so arranging the

circuit that, when the selector is stepped to a specific level, the marking conditions on the *P*1 bank provide a circuit for the release magnet to restore the selector shaft to normal. The introduction of the 2000 type selector, with its different type of release action, produces some difficulties in this respect. With such a selector the wipers must be rotated under self-drive conditions over the level before the wiper carriage can restore to its normal position. This release movement must be completed during the intertrain pause, and under some conditions there is very little margin of safety. The alternative is to introduce digit storage facilities and to suppress any initial impulse trains in the storage device rather than to release the selector after it has been stepped.

These and other considerations have led to the introduction of the satellite discriminator scheme shown in Fig. 373. The subscribers' uniselectors give access to satellite 1st selectors which, in some respects, are similar to the 1st code selectors of the director system (q.v.). The selectors are, in essence, 200-outlet group selectors. Associated with each 1st selector is a 25-point uniselector known as a *discriminator hunter* which gives access to a group of *discriminators* common to the exchange. The discriminator contains a pair of uniselectors, a mechanical impulse regenerator, and a number of relays.

When a subscriber lifts his receiver, the seizure of a 1st selector by his uniselector causes the discriminator hunter to search for a disengaged discriminator. The 1st selector includes an impulse repetition bridge, so that the digits dialled by the subscriber are repeated via the discriminator hunter to the discriminator circuit. The impulses are there stored in the mechanical impulse regenerator and are also used to step the discriminating uniselectors. The positions to which the uniselectors are stepped determine whether the call is local or is to be routed via the main exchange, the appropriate fee, or (on non-metered calls) whether manual hold is to be applied, whether first digit absorption is required, and so on. The appropriate conditions are recorded by the operation of various relays in the discriminator which are connected to the uniselector banks as required. If the call is local, the stored impulse trains are re-transmitted immediately the routing has been determined. If absorption of the first digit is required, this is obtained simply by suppressing the first digit transmitted from the regenerator.

Another interesting feature of the scheme is the utilization of one or more levels of the satellite 1st selector as a junction hunter for calls to be routed via the main exchange. It has been seen (Fig. 368) that, with the pre-2000 type discriminating selector scheme, a separate junction hunter of the uniselector type is provided to pre-select a disengaged junction to the main exchange. This mechanism has been entirely eliminated in the new scheme by the provision of circuit facilities whereby the discriminator can cause the satellite 1st selector to hunt automatically over predetermined levels when a call via the main exchange is required. This feature does, of course, restrict the number of 1st selector levels which is available in the local numbering scheme, but an examination of a large number of practical cases has shown that this does not materially restrict the trunking arrangements at the satellite exchange.

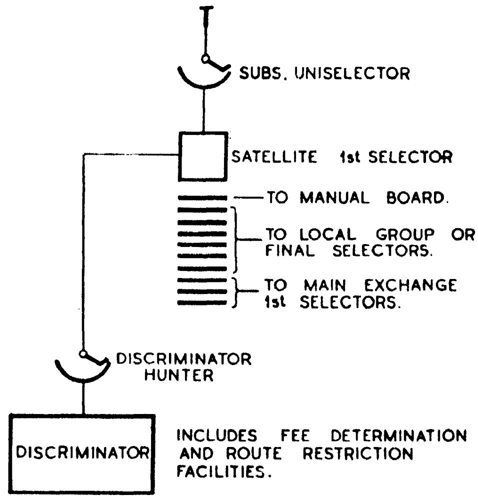


FIG. 373. MAIN TRUNKING FEATURES OF 2000 TYPE SATELLITE EXCHANGE

If necessary, all the main exchange junctions can be accommodated on the 1st level with a grading scheme to obtain the maximum circuit efficiency. Alternatively (if the numbering scheme permits), the junctions to the main exchange can be arranged as a full availability group with the outlets spread over two, three, or more levels of the 1st selectors. The facility of being able to use large full availability groups in some instances makes it possible to produce material economies in the number of circuits to the main exchange, and the number of 1st selectors at the main exchange. It should be noted that, when a call is to be routed via the main exchange, the regenerator does not commence to transmit the stored digits until a signal is received to indicate that a junction to the main exchange has been seized. There is, therefore, no fundamental limitation to the hunting time on the main junction group.

On all non-metered calls, it is possible to release the discriminator immediately the connexion has been established, but if the call is chargeable, the discriminator must be held until the called party replies and the necessary fee has been recorded. At this point the discriminator can be released for use on other calls.

An important feature of the separate discriminator scheme is the ease with which modifications can be made to the discrimination, metering, and other features. The various relays and the uniselector outlets are terminated on a connexion strip in the discriminator, so that the cross-

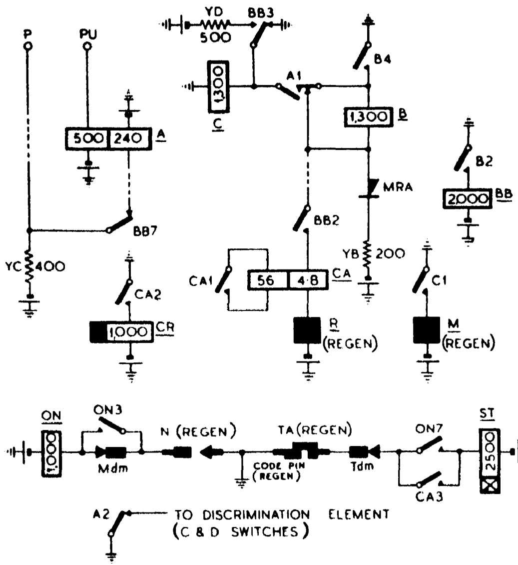


FIG. 374. STORAGE ELEMENT OF DISCRIMINATOR CIRCUIT

connexions can be readily modified by altering the strapping on this connexion strip.

Attention should perhaps be drawn to the fact that, although the discriminator provides impulse regeneration, this is not really necessary from the point of view of improving the impulsing performance over the junction network. As will be seen later, the normal practice in a non-director exchange area is to provide auto-to-auto relay sets which incorporate impulse regenerators, when necessary, on outgoing routes to exchanges outside the linked numbering scheme. These regenerators are also in circuit on calls from a satellite exchange, and provide a complete re-formation of the impulses on such calls.

It is desirable, in view of the complexity of the discriminator circuit, to consider its several functions as separate elements before examining the discriminator circuit as a whole.

Storage Element. Fig. 374 shows the portion of the discriminator circuit concerned with the receipt of the incoming impulse trains and their storage on the impulse regenerator. The *A* relay is pre-operated on its 240 Ω coil by earth on the *P*-wire extended by the discriminator hunter. ***A*1** energizes the *B* relay, whilst ***B*2** operates the relief relay *BB*. ***BB*7** now disconnects the pre-operate circuit of *A* and thereby places the *A* relay under the control of the earth on the pulse wire (*PU*). The circuit is now ready for the impulse trains, which are received in the form of disconnexions of the earth on the *PU*-wire. The *A* relay releases at each impulse, and at *A*1 repeats the impulse to the receive magnet of the regenerator. At the first release of *A*1, the short circuit is removed from the *C* relay, which now operates to the battery at resistor *YD*. The short circuit across the *C* relay is re-applied at each operation of ***A*1** between successive impulses, but the slow release feature produced by the short-circuiting of the relay coil prevents the release of the *C* relay until the end of the impulse train. The operation of ***C*1** energizes the marking magnet (*M*) of the regenerator, so that the marking lever is lifted clear of the marking pins whilst the storage wheel is rotated by the *R* magnet (see also Fig. 231). The *CA* relay, in series with the *R* magnet, operates at the first impulse, and the slow release feature produced by the short-circuited second coil, maintains the relay until the end of the impulse train.

Contact ***CA*2** operates the slow-to-release relay *CR*, and the *CA* and *CR* relays together provide a timing period for the discriminating relays (described later). ***CA*3** operates the *ST* relay in readiness for pulsing out at a later stage. At the end of the first digit, relays *C*, *CA*, and *CR* release. *C*1 disconnects the circuit of the *M* magnet so that the marking lever restores and depresses the marking pin appropriate to the first digit. Subsequent digits are received and "marked out" in a similar manner. The mechanical arrangements of the regenerator are such that the off-normal springs (*N*) are closed on receipt of the first impulse and remain closed until all digits have been re-transmitted and the regenerator is normal. The closure of the *N* springs operates relay *ON* when the marking magnet contacts (*Mdm*) close at the end of the first digit. The *ON* relay locks via its own contact (***ON*3**) until such time as the regenerator returns to normal. Contacts ***ON*7** provide a locking circuit for the *ST* relay whilst other contacts of the *ON* relay (not shown) prepare the pulsing-out circuit.

Discrimination Circuit. Fig. 375 shows the connexions of the discriminating uniselectors and

the associated relays. For purposes of illustration, cross-connexions between the discriminating relays and the C and D switch banks are shown for seven typical calls. Relays A, B, BB, and ON are operated during pulsing-in as already described.

Case 1. *Assume that the dialling code "883" has been allotted for obtaining access to an automatic exchange which is outside the linked numbering* earth at **B3**. Other contacts of the JD relay (described later) signal to the 1st selector that automatic hunting for a line in the main exchange junction group is required.

Some 400 msec after the release of $CA4$, the CR relay restores to normal, and at $CR3$ switches the discriminating earth to the $C1$ wiper. A drive circuit is thereby completed for

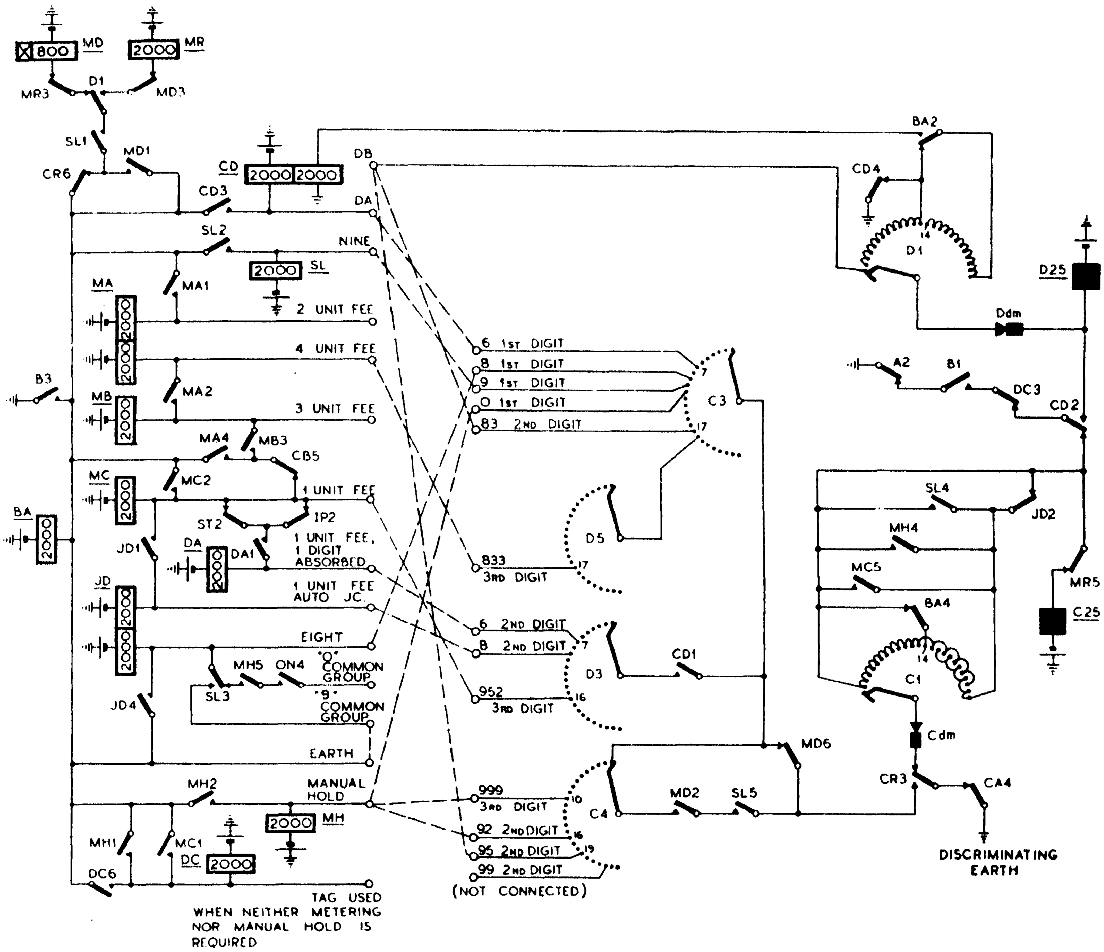


FIG. 375. DISCRIMINATION ELEMENTS

scheme; also that discrimination is to be effected on the third digit and that the appropriate fee is 4 units.

The first digit ("8") causes the C switch to make 8 steps so that the wipers now rest on contact 9. Relays CA and CR are operated during receipt of the digit (see Fig. 374), and, at the end of the impulse train, the release of $CA4$ extends earth via the $C3$ wiper and the 9th contact of the uniselector bank, to operate the 8th level discriminating relay JD. The latter relay locks via **JD4** to the common the C switch driving magnet until the wipers reach contact 14. At this point the drive circuit is halted by the operated condition of contact **BA4**.

On receipt of the second digit ("3") the C switch makes 3 further steps (i.e. to contact 17) under the control of $A2$. When contact $CA4$ restores at the end of the second digit, earth is extended via the $C3$ arc and the home contact of the $D1$ arc to energize the D switch magnet. The D switch therefore makes one step and then self-drives

to the earth on the second and subsequent contacts of the $D1$ arc. When contact 14 is reached, the CD relay operates to the driving magnet battery, and the drive is arrested due to the high resistance of this circuit. CD locks on its second coil to the common earth, and at ***CD*2** changes over the digit reception circuit from the C switch to the D switch. At the end of the second discriminating interval (i.e. on the release of relay CR), earth is extended to the $C1$ arc to cause the C switch to make one further step to contact 18. The bank commoning is now such that the switch will drive home as soon as fee discrimination has been completed.

During receipt of the third digit ("3") the D switch makes 3 steps (i.e. to contact 17) under the control of $A2$. During the third discriminating interval at the end of this digit the earth from $CA4$ operates the MA relay via the $D5$ arc. MA locks at ***MA*1**, whilst ***MA*2** completes a circuit for the MB relay. The MB relay in turn locks via ***MB*3** and ***MA*4** to the common earth. ***MA*4** also operates the MC relay, which locks at ***MC*2**, whilst the ***MC*1** contact completes the circuit for the DC relay which also locks via its own contact (***DC*6**). ***DC*3** is provided to isolate the discrimination circuit from any further digits dialled by the caller.

The operation of the MA, MB, and MC relays together sets up the required 4-unit fee condition in the metering group. At the end of the third discriminating signal (i.e. when $CR3$ releases), the C switch drives to contact 1 in readiness for the metering and release cycle.

Case 2. *Assume a* 1-*unit fee call with second digit discrimination to subscriber No.* 6842 *on the main or a distant satellite exchange.*

The first digit ("6") positions the C switch on contact 7, and during the first discriminating interval (i.e. on the first release of $CA4$) the CD relay operates via the $C3$ arc and locks at ***CD*3**. ***CD*2** now changes over the digit reception circuit from the C switch to the D switch. At the end of the first discriminating interval (when $CR3$ restores), the C switch drives via the $C1$ arc to contact 14 where it is halted by the open ***BA*4** contact. The 14th rotary position of the C switch is a start position for the metering and release cycle, and there is, therefore, no need to home this C switch as described in the previous case.

The second digit ("8") positions the D switch on the 9th contact, and during the second discriminating interval JD operates via the $D3$ arc and ***CD*1** to the $CA4$ earth. JD locks at contact ***JD*4** and, as before, other JD contacts signal to the 1st selector that hunting is required on the main exchange common group of junctions. ***JD*1** completes a circuit for the MC relay to the $CA4$ earth, and the MC relay locks via ***MC*2** to the common earth. ***MC*1** now completes a circuit for DC which locks at ***DC*6**, ***DC*3** again isolating the impulsing circuit to prevent further digits interfering with the positioning of the C and D switches.

The operation of the MC relay alone sets up the required single-fee metering condition.

Case 3. *Assume a call to subscriber No.* 6642 *on the local exchange where first digit absorption, second digit discrimination, and single-fee metering are required.*

The dialling of the first digit ("6") positions the C switch wipers on the 7th set of contacts. During the first discriminating interval the $CA4$ earth, extended via the $C3$ arc, operates the CD relay which locks at ***CD*3**. ***CD*2** changes over the digit reception circuit from the C switch to the D switch. At the end of the discriminating interval (i.e. when $CR3$ restores), the C switch drives to position 14 in readiness for the commencement of the metering cycle.

When the caller dials the second digit ("6"), the D switch makes 6 steps to position the wipers on the 7th set of contacts, and, during the second discriminating interval, the DA relay operates via the $D3$ arc and ***CD*1** to the $CA4$ earth. A contact of relay DA (described later) short-circuits the regenerator impulsing springs to provide absorption of the first digit. The operation of ***DA*1** completes a circuit for the MC relay, which locks and provides the required single-fee metering condition. ***MC*1** also operates the DC relay to prevent interference from succeeding digits.

The non-operation of the JD relay on this call prevents the seizure of a main exchange junction, and the satellite 1st selector is stepped to the second digit stored in the regenerator to route the call to the required local number.

Case 4. *Assume an* "0" *level call routed over a special group of high-grade junctions from the* 10*th level of the* 1*st selectors. Manual hold is required, but no metering.*

The dialling of the digit "0" causes the C switch to make 10 steps to position the wipers on contact 11. During the discriminating interval, relay MH operates via the $C3$ arc to the earth at contact $CA4$. A holding circuit is provided at ***MH*2**, whilst a further contact (not shown in Fig. 375) signals to the selector that manual hold is required. ***MH*1** energizes the DC relay to prevent any further irregular impulses from affecting the discrimination circuit. At the end of the discriminating interval, the C switch drives to contact 14 in readiness for the metering cycle but, since

all the metering relays are normal, no metering can take place on this call.

It should be noted that if, in any particular circumstances, "0" level calls are to be routed via the main exchange common group of junctions, the "0 common group" terminal is strapped to the "earth" terminal in the discriminator. This provides a circuit for the operation of relay *JD* via ***MH*5** and ***ON*4** in order to signal to the selector that hunting is required over the main exchange junction group.

Case 5. *Assume a call to the Service P.B.X. (dialling code "92"). The call is to be routed via the main exchange with second digit discrimination. No fee is chargeable, but the manual hold facility is to be provided.*

The initial digit ("9") positions the *C* switch wipers on the 10th set of contacts, and, during the first discriminating interval, the *SL* relay operates via the *C*3 arc to the earth at *CA*4. ***SL*2** provides a locking circuit for relay *SL*, whilst ***SL*3** operates *JD*. The *JD* relay locks at ***JD*4**, and other contacts of this relay signal to the selector that hunting is required over the main exchange group.

On the release of *CR*3, the *C* switch drives to contact 14. At the same time the *MD* relay operates via ***SL*1** and *CR*6 to the common earth. *MD* locks at ***MD*1**.

The second digit ("2") is received on the *C* switch due to the non-operation of the *CD* relay. The *C* switch therefore makes 2 further steps to contact 16, and, during the second discriminating interval, the *MH* relay operates via the *C*4 arc and ***MD*2** and ***SL*5** to the *CA*4 earth. *MH* holds at ***MH*2**, whilst a further contact of *MH* transmits the manual hold signal to the selector. ***MH*1** operates the *DC* relay as previously described to prevent interference from any further impulses dialled by the subscriber.

At the end of the second discriminating interval the *C* switch drives to contact 1 in readiness for the release of the discriminator.

In certain cases "9" level calls may be routed via a special group of high-grade junctions. In these circumstances the strapping inserted between the "9 common group" and "earth" terminals is omitted. The operation of the *SL* relay does not then cause operation of *JD*, and the main exchange group hunting signal is not transmitted. The satellite 1st selector is stepped to level 9 in the ordinary way by the regenerator.

Case 6. *Assume a call to the Speaking Clock (code "952") over the main exchange junction group. Third digit discrimination and unit fee registration are required.*

On this call the *C* switch steps to the 10th contact on receipt of the first digit. The *SL* relay operates during the first discriminating interval as previously described, and the ***SL*3** contact operates the *JD* relay to provide automatic hunting over the main exchange junction group. At the end of this discriminating interval, the *C* switch drives to contact 14, and the *MD* relay operates via ***SL*1** and *CR*6. The caller dials the second digit ("5") to step the *C* switch a further 5 steps to contact 19. During the second discriminating interval, the *D* switch is stepped from its normal position from the earth extended via the *C*4 arc, ***MD*2** and ***SL*5**. It now self-drives to contact 14 where relay *CD* operates. ***CD*2** changes over the digit reception circuit from the *C* switch to the *D* switch and, at the end of the second discriminating interval, the *C* switch drives to contact 1.

The caller dials the third digit ("2") to step the *D* switch to contact 16 and, during the third discriminating interval, the *MC* relay operates via the *D*3 arc and ***CD*1** to the *CA*4 earth. *MC* operates relay *DC* to isolate the discriminator circuit from further impulsing. The operation of the *MC* relay establishes the necessary condition for unit fee metering.

Case 7. *Assume an emergency call (code "999") over the main exchange group of junctions. Third digit discrimination and manual hold are required, but no fee is chargeable.*

The first digit ("9") positions the *C* switch on the 10th set of contacts and, during the first discriminating interval, relays *SL* and *JD* are operated. At the end of this interval the *C* switch drives to contact 14 as before, and the *MD* relay operates (via ***SL*1** and *CR*6).

The second digit ("9") is again received on the *C* switch, which makes 9 further steps to contact 23. At the end of the second discriminating interval, the *C* switch makes one self-driven step independently of *SL*4, and two similar steps via ***SL*4** operated, thereby arriving back at its home contact (No. 1).

The third digit ("9") is also received on the *C* switch, which now steps to the 10th contacts. During the third discriminating interval, the *MH* relay operates to indicate that manual hold is required, whilst ***MH*1** operates *DC* as usual. At the end of the third discriminating interval, the *C* switch drives to contact 14 in readiness for the release cycle.

Pulsing-out Element. Fig. 376 shows the portions of the discriminator circuit which are concerned with pulsing out and the passing of the necessary signals to the 1st selector for automatic hunting

over the main exchange junction route, for manual hold, etc. The *ON* relay is operated whenever the regenerator is "off-normal" (i.e. so long as it contains undischarged digits) and relay *ST* is operated and held by *ON*7.

On calls via a satellite 1st selector level (i.e. calls not routed via the common group of junctions to the main exchange), the *MD* relay (not shown in Fig. 376) operates as soon as discrimination takes place. ***MD*4** completes a circuit for the *T* magnet which now operates the trip arm (*TA*) and re-sets the code pin with which the arm is engaged. The trip magnet interrupter contacts ***Tdm*** open and release the *ST* relay. *ST*1 now disconnects the *T* magnet circuit, and the trip

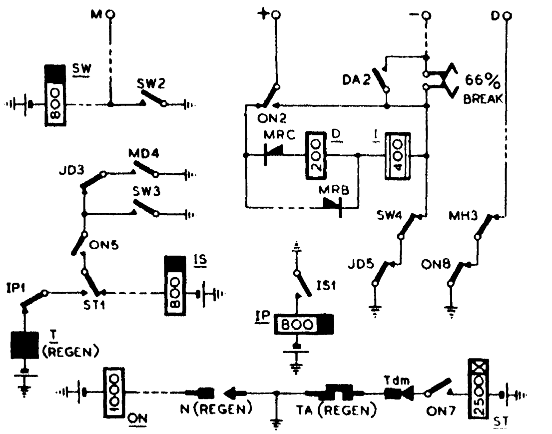


FIG. 376. PULSING-OUT CIRCUIT OF DISCRIMINATOR

arm is withdrawn from the re-set code pin. The impulse wheel (and the trip arm assembly) is now rotated by the spring of the regenerator, and earth disconnexion impulses are sent out over the negative wire to step the 1st selector. The release of *ST*1 operates the *IS* relay, and ***IS*1** in turn operates *IP*. When the trip arm encounters the first digit pin (previously set by the storage mechanism) the sending element is halted, and relay *ST* re-operates to the earth at the code pin. The slow operate feature of the *ST* relay forms the first part of the intertrain pause.

When the 1st selector seizes a free trunk on the selected level, earth is returned on the *M*-wire to operate relay *SW*. *SW* locks at ***SW*2**, whilst ***SW*4** removes the earth from the impulsing loop in readiness for the impulsing to second and subsequent selectors.

After the slow operate period of relay *ST*, the changeover of ***ST*1** disconnects *IS*, and the release lag of this relay provides the second part of the intertrain pause. In due course, *IS* restores and *IS*1 disconnects *IP* which is also slow-to-release, and forms the third and last part of the intertrain pause. When *IP*1 is normal the *T* magnet is re-energized, and the trip arm (*TA*) re-sets the first digit code pin. The *ST* relay is released at the trip magnet interrupter contacts, and, when *ST*1 restores, the *T* magnet is released and the trip arm is withdrawn from the re-set code pin. The impulse wheel and the trip arm assembly is now free to rotate for the transmission of the second digit (this time as loop-disconnect impulses over the − and + wires). When *ST*1 restores, *IS* and *IP* are operated as before. When the trip arm encounters the projecting second digit code pin, the sending mechanism is halted and another intertrain pause is provided, as already described.

When all stored digits have been transmitted, the regenerator off-normal contacts (*N*) open to release the *ON* relay. *ON*2 disconnects the impulsing loop and restores the *D* and *I* relay loop in readiness for the reception of supervisory signals. *ON*7 prevents re-operation of *ST* from the earth at the depressed code pin at which the mechanism is now camped.

If first digit absorption is required, relay *DA* operates as already explained in connexion with Fig. 375. Contact ***DA*2** short-circuits the impulse springs to render the transmission of the first digit ineffective. The satellite 1st selector therefore steps to the second transmitted digit.

When manual hold is required, the *MH* relay is operated. ***MH*3**, by disconnecting the *D*-wire, forwards the manual hold signal to the selector.

On calls to be routed via the common group of junctions to the main exchange, relay *JD* is operated and ***JD*5** disconnects the earth from the pulsing-out loop. This loop signal (as distinct from the normal earthed-loop) causes the 1st selector to hunt automatically over the levels containing the junctions to the main exchange. During hunting, contact ***JD*3** renders contact *MD*4 ineffective, thereby holding up the transmission of the impulse trains.

When a selector at the main exchange has been seized, pulsing out from the discriminator is started by the operation of the *SW* relay from an earth on the *M*-wire returned by the selector. ***SW*3** now provides the initial earth to operate the *T* magnet which initiates the pulsing-out cycle. It will be noted that the operation of the *SW* relay also disconnects the earth from the pulsing-out loop so that all digits (including the first) are loop-disconnect impulse trains.

Metering and Release Elements. Fig. 377 shows the elements of the discriminator circuit concerned with metering and with release. It will be recalled

from the descriptions given in previous paragraphs that relay *DC* is operated on every call during discrimination. Contact **DC1** in turn provides a pre-operate circuit for the metering delay relay *MD*. It will also be recalled that the *C* switch of the discriminator is always driven to contact No. 1 or to contact No. 14 either during or after discrimination. These are the start positions for the metering and release sequence. The *C*5 arc is commoned so that contacts 1–10 are multipled to contacts 14–23.

The metering discrimination relays (*MA*, *MB*, and *MC*) are arranged so that *MC* is operated on all metered calls, irrespective of the unit value of the call. Contacts of *MC* can therefore be used to differentiate between metered and non-metered calls. In Fig. 377 the *D* relay will respond to any current in the junction loop when contact *MC*3 is normal (i.e. the *D* relay is not polarized under these conditions). On non-metered calls, therefore, the *D* relay operates immediately after the completion of pulsing out (from the battery and earth returned from the distant exchange). If, on the other hand, the call is chargeable, relay *MC* is operated and the resultant polarization of the *D* relay prevents its operation until the called subscriber replies, i.e. when the current in the junction loop is reversed. Hence, on non-metered calls the **D1** contact is arranged to start up a discriminator release sequence as soon as the connexion has been established. On metered calls the discriminator must be held until the called party replies, and in such cases the **D1** contact starts the metering cycle, the discriminator being released only when metering has been completed.

For purposes of illustration let it be assumed that a 2-unit fee call has been set up. Relays *MA* and *MC* will have operated, and on receipt of the called party's answering signal relay *D* operates. **D1** releases *MD*, and *MD*3 provides an operate circuit for *MR*. *MR* locks via **MR1** to the common **B3** earth. The release of *MD*5 completes a circuit for the *MP* relay via contact 1 (or 14) of the *C*5 arc to the earth at **MR2**. The *C* switch driving magnet is now energized via **MP1** and **MR5**. The closure of the **MR1** and **MP2** contacts provides a re-operate circuit for the *MD* relay, and **MD5** releases *MP*. The *C* magnet is now de-energized, and the *C* switch steps to contact 2 (or 15). A circuit is now completed for the *MG* relay which operates via **MC6** and the *C*5 arc, to the earth at **MR2**. **MG1** applies the first pulse of positive battery to the meter wire of the 1st selector. After a release lag, the *MP* relay restores, and at *MP*2 disconnects the *MD* relay. After a further period of lag, the reclosure of contact *MD*5 allows the *MP* relay to re-operate via **MG2** to the **MR2** earth. **MP1** energizes the *C* switch magnet for a second time, whilst **MP2** re-operates *MD*. The opening of contacts **MD5** releases the *MP* relay, thereby de-energizing the magnet circuit at *MP*1. The *C* switch wipers are thereby stepped to contact 3 (or 16). The circuit for the *MG* relay is now broken at the *C*5 arc, and the restoration of *MG*1 disconnects the first pulse of the positive battery metering signal.

The restoration of *MP*2 disconnects *MD*, and, when *MD*5 is normal, the *MP* relay re-operates as

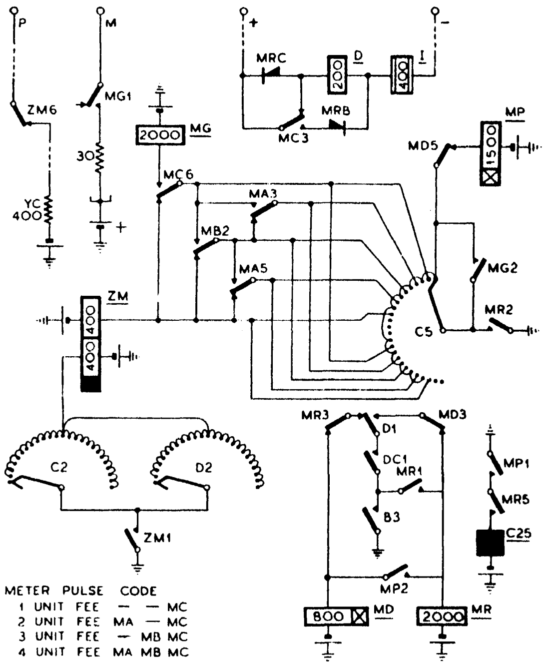


FIG. 377. METERING AND RELEASE CIRCUITS OF DISCRIMINATOR

already described. The *C* switch magnet is energized for the third time at **MP1**, whilst **MP2** re-operates *MD*. **MD5** again disconnects *MP*, and by this means the *C* switch wipers are stepped to the 4th (or 17th) contact. A circuit is now provided for the re-operation of the *MG* relay via **MA3** and **MC6**, and the second meter pulse begins. The cycle of relay and switch operations continues until the *C* switch steps to the 5th (or 18th) contact, when *MG* releases and at *MG*1 terminates the second meter pulse. Relay *MD* now releases, and the *MP* relay re-operates, the *C* switch magnet being energized at **MP1**. **MP2** re-operates *MD*, and **MD5** disconnects *MP* to step the *C* switch to the 6th (or 19th) position.

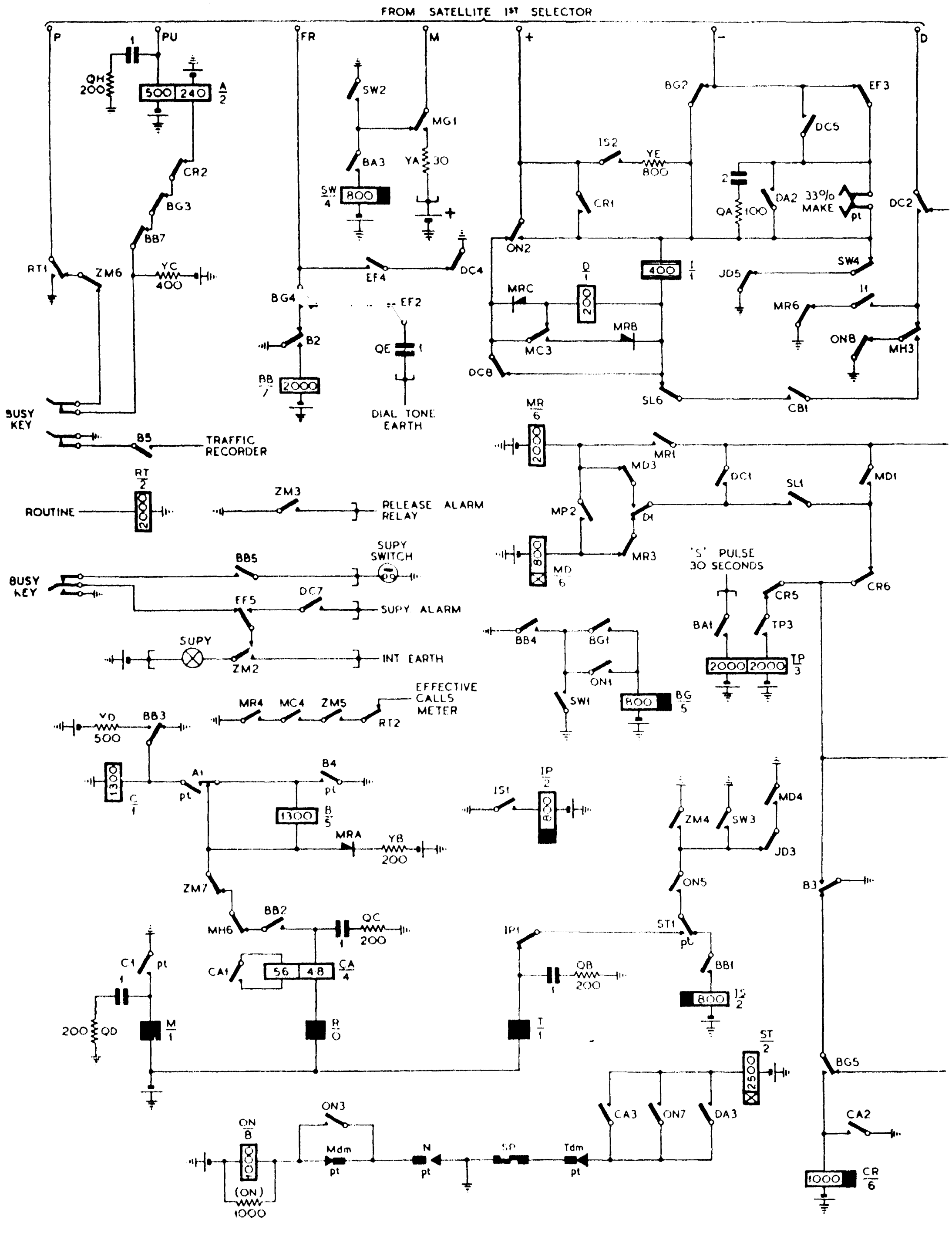
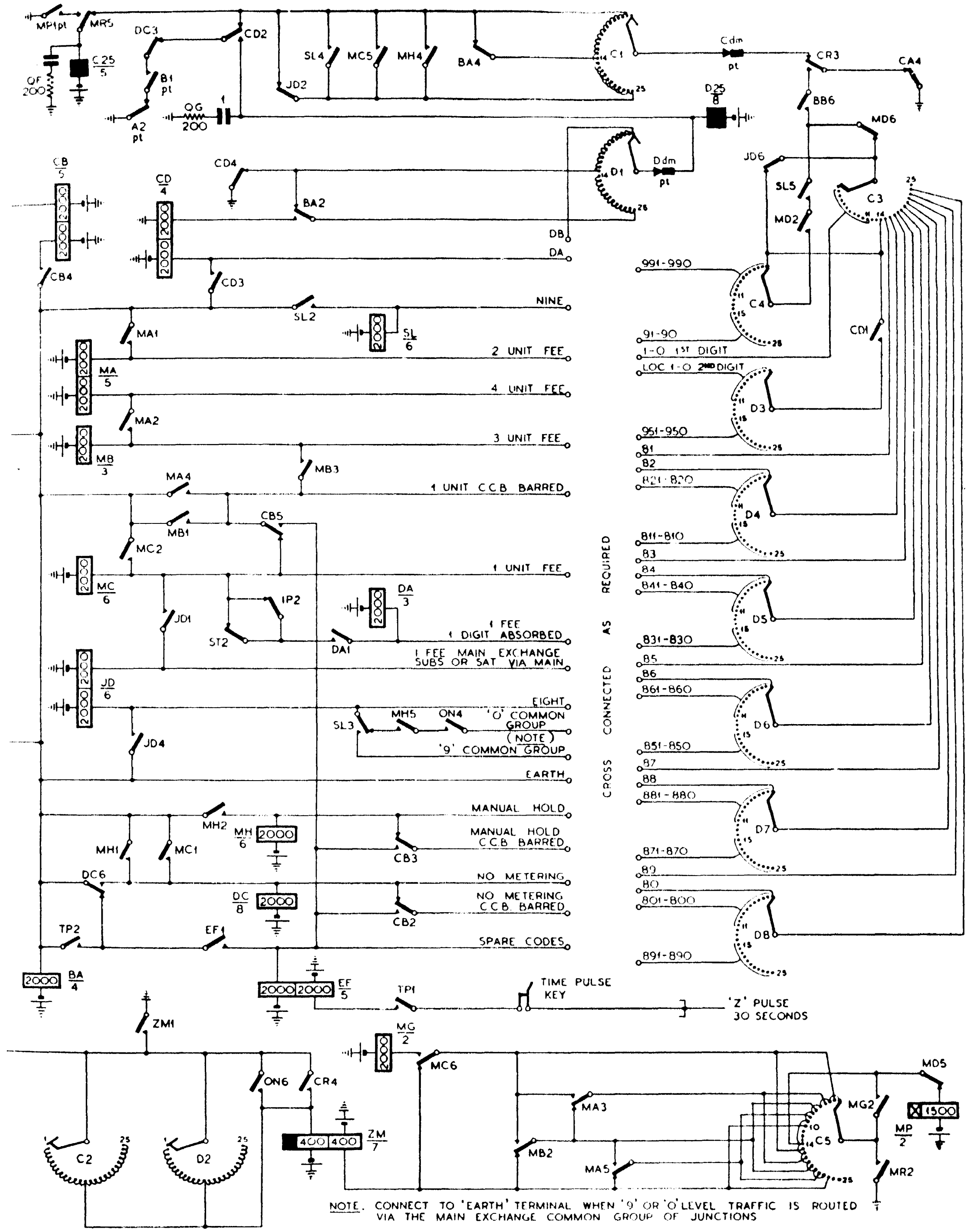


Fig. 378. Comple



DISCRIMINATOR CIRCUIT

The *ZM* relay now operates via *MB*2 and locks to the earth via the *C*2 arc. The contacts of the *ZM* relay cause the complete release of the discriminator, e.g. ***ZM*6** disconnects the *P*-wire, etc.

On non-metered calls (when the *D* relay operates to the battery and earth conditions from the distant relay set as soon as the connexion is established), the release relay *ZM* operates via *MC*6 to the earth at the *C*5 arc as soon as the *C* switch makes its first step.

Complete Discriminator Circuit. The complete circuit of the satellite exchange discriminator is given in Fig. 378. The circuit provides the following facilities:

(1) It transmits dial tone to the caller when the circuit is seized by a satellite 1st selector.

(2) It accepts and stores the impulse trains dialled by the subscriber.

(3) It provides first or second digit discrimination on calls to exchanges within the linked numbering scheme.

(4) Provision is made for the absorption of the first digit if required.

(5) Second or third digit discrimination can be provided on calls to exchanges outside the multi-exchange area.

(6) Second digit discrimination is available on "9" level calls, and third digit discrimination is provided on calls to the "95" and "99" levels.

(7) Facilities are provided to route "9" and "0" level calls either over a common group of junctions to the main exchange or, alternatively, over two separate junction groups.

(8) Provision is made for fee discrimination of from 1 to 4 units.

(9) There is non-metering discrimination available with or without the manual hold facility.

(10) Facilities are provided for barring coin-box calls on multi-fee routes.

(11) Access is barred if the calling subscriber dials a spare code.

(12) The discriminator is normally released on the completion of metering, but on non-metered calls the release of the discriminator takes place on the completion of pulsing out. (An exception to this is on "0" level calls from coin-box users when the discriminator is held until the operator answers.)

(13) The discriminator is also released if a caller dials any barred code or if there is a delay in dialling.

(14) The normal supervisory and release alarms are provided.

(15) The design is such that the junction is adequately guarded under forced or premature release conditions.

(16) The circuit also provides for the guarding of the discriminator hunter outlets until the discriminator circuit is completely normal.

(17) Facilities are provided for traffic recording and for the registration of effective calls. There are also facilities for routine testing and for placing the discriminator out of service by the operation of the busy key.

The main features of the circuit operation have already been described in previous paragraphs, and there should be no difficulty in understanding the complete circuit.

Satellite 1st Selector. Fig. 379 shows the circuit of the satellite 1st selector designed for use in conjunction with the discriminator already described. The selector is essentially a 200-outlet group selector with facilities for automatic search over certain levels on receipt of a signal from the discriminator. The selector includes a ballast resistor transmission bridge of the capacitor-impedance type, and incorporates the necessary testing and switching relays for the control of the discriminator hunter (which is associated with the selector). Facilities are also provided for manual hold and for the guarding of outgoing junctions on release.

The circuit is seized by a subscriber's uniselector, and relay *L* operates to the subscriber's loop. ***L*1** provides a pre-operate circuit for relay *A* on the 2000 Ω winding, and ***A*1** prepares the switching relay (*K*) circuit of the discriminator hunter. ***A*4** operates the *B* and *C* relays, and ***B*2** in turn guards the incoming *P*-wire and operates the relief relay *BB*.

The closure of the ***C*2** contact completes the driving magnet for the discriminator hunter, and the wipers are rotated until such time as battery is encountered on the *P*-wire. The *K* relay circuit is a normal battery testing circuit with differential-hold conditions as already described in Chapter VII. When *K* operates, the ***K*1** contact disconnects the discriminator hunter drive, whilst ***K*2** energizes the relief relay *KR*. Contacts ***KR*2** and ***KR*5** now extend the earthed loop from the discriminator to the impulsing relay (*A*). The earth from the discriminator on the negative wire provides an alternative holding circuit for the *A* relay, the pre-operate circuit now being disconnected at ***KR*3** which also extends the ***L*1** earth to the pulse wire of the discriminator.

The caller now receives dial tone from the discriminator and proceeds to dial the required number, relay *L* responding to the loop-disconnect impulses and repeating them as interruptions of earth on the *PU*-wire. The subsequent operation depends upon the type of call, i.e. if the call is

to be routed over the main exchange junction circuits, or via the satellite 1st selector levels. The two main cases will be considered separately.

Call via 1st Selector Levels. If digit absorption is not required, the discriminator pulses out the first digit as soon as discrimination has been effected. Alternatively, if digit absorption is provided, the first impulse train is suppressed in the discriminator and the satellite 1st selector responds to the second digit. In either case the impulse train received is in the form of disconnexions of the earthed negative wire from the discriminator. The *A* relay of the selector responds to these impulses and steps the vertical magnet at *A*4. At the first vertical step, the off-normal springs open and the *C* relay is made dependent upon the pulses of current in its low resistance winding. It will be noted that, during vertical stepping, the ***V*1** contacts close at each step, but the presence of the earth on the loop in the discriminator renders the *V*1 contacts ineffective.

At the first vertical step, relays *HA* and *HB* operate in readiness for the testing of the outlets on the selected level. At the end of the impulse train, the release of *C*6 completes the rotary drive circuit, and the wipers are stepped by the interaction of the *R* magnet and the *R*1 springs. So long as the *P*1 and *P*2 wipers encounter the engaged condition (earth), the *HA* and *HB* relays hold and the drive circuit is maintained. When a free outlet is encountered, the absence of earth on the *P*-wire allows either *HA* or *HB* to release. The circuit is similar to the normal 200-outlet group selector described in earlier chapters, and provision is made for preferential switching to the first outlet of the pair if the wipers encounter the free condition on both the *P*1 and *P*2 arcs.

When a free outlet is seized, the release of *HA*5 or *HB*7 provides a circuit for relay *BA*, whilst ***BA*2** and ***BA*5** now extend the pulsing-out loop from the discriminator to the next selector in the train. ***BA*1** provides an alternative holding circuit for the *A* relay, whilst ***BA*3** extends the ***B*2** earth over the *M*-wire to the discriminator. On receipt of this signal the discriminator removes the earth from the pulsing-out loop in order to provide normal loop-disconnect impulsing to the second and subsequent selectors.

When the discriminator commences its release cycle, the *P*-wire to the 1st selector is disconnected, thereby releasing relays *K* and *KR*. *KR*3 and *KR*6 restore the *A* relay to the control of the ***L*1** contact, whilst *KR*2 and *KR*5 complete the transmission bridge for conversation. *KR*4 releases *KK*, and *KK*8 (in conjunction with *K*1) completes a homing circuit for the discriminator hunter.

When manual hold is not required, the discriminator does not disconnect the *D*-wire, and hence relay *MH* of the 1st selector operates to earth extended by the discriminator. *MH* continues to hold after the discriminator has been released over a circuit provided by contacts ***MH*3** and *KR*7 to the earth at ***BB*4**. The operation of ***MH*4** under these conditions prevents the application of manual hold.

In circumstances where manual hold is required, the disconnexion of the *D*-wire in the discriminator releases relay *MH* but, since ***KR*7** is at this time operated, there is no alternative holding circuit for the *MH* relay, and the latter restores. If, now, the *L* relay is released by the calling subscriber, the normal holding circuit for the *A* relay is disconnected at *L*1, and contact *A*2 restores. The *MH*4 earth is now extended via the 400 Ω coil of the *I* relay to the positive wire. The *I* relay is therefore held by the battery returned from the distant exchange over the positive wire, and ***I*1** maintains the *B* relay. By this means the call is held under the control of the distant exchange operator.

Call via Main Exchange Junction Group. If a call is to be routed over the common group of junctions to the main exchange, the satellite 1st selector is required to operate as a junction hunter, i.e. to search automatically over all junctions to the main exchange.

A relay (*G*) is connected to the *P*-wire of all outgoing junctions so that the relay is operated whenever the outgoing junction is engaged. The contacts of the *G* relay are wired in parallel so that an earth is maintained on the vertical marking bank of the selector whenever there are free junctions on that level (see inset of Fig. 379). If all junctions on one level are engaged, the operation of all the ***G*1** contacts removes the vertical marking bank earth for that particular level. The circuit is arranged so that, if earth is encountered on the vertical marking bank, the selector cuts into that level and carries out rotary search. The last level of the main exchange junction group is treated as a special case, its vertical marking bank contact being permanently earthed. When the group is fully engaged, therefore, the selector cuts into the last level, rotates to the 11th step, and returns the engaged signal to the caller.

It has been seen that, when a discriminator has been taken into use, the *A* relay of the selector is held by an earth over the negative wire. As soon as the incoming impulse trains indicate that the call is to be routed via the main exchange, the

discriminator disconnects the earth from the pulsing-out loop. The *A* relay now releases, and the release of *A*4 causes the vertical magnet to make one step. The *V*1 springs now close and the *A* relay re-operates on its 500 Ω coil over the loop formed through the discriminator, via contact ***BA*5** to the earth at ***V*1**. The re-operation of ***A*4** disconnects the vertical magnet and the *V*1 springs open. If all junctions on the first level are engaged, relay *A* releases. A circuit is now completed for a second operation of the vertical magnet, and the cycle continues for so long as no earth is encountered by the vertical marking wipers. When a level is reached where there is at least one free junction, the selector *A* relay is held from the earth at the vertical marking bank. Relay *C* now releases (the initial operating circuit is, of course, broken at ***N*4**), and relays *HA* and *HB* are energized. The circuit is now set for rotary search for a free junction in the normal manner.

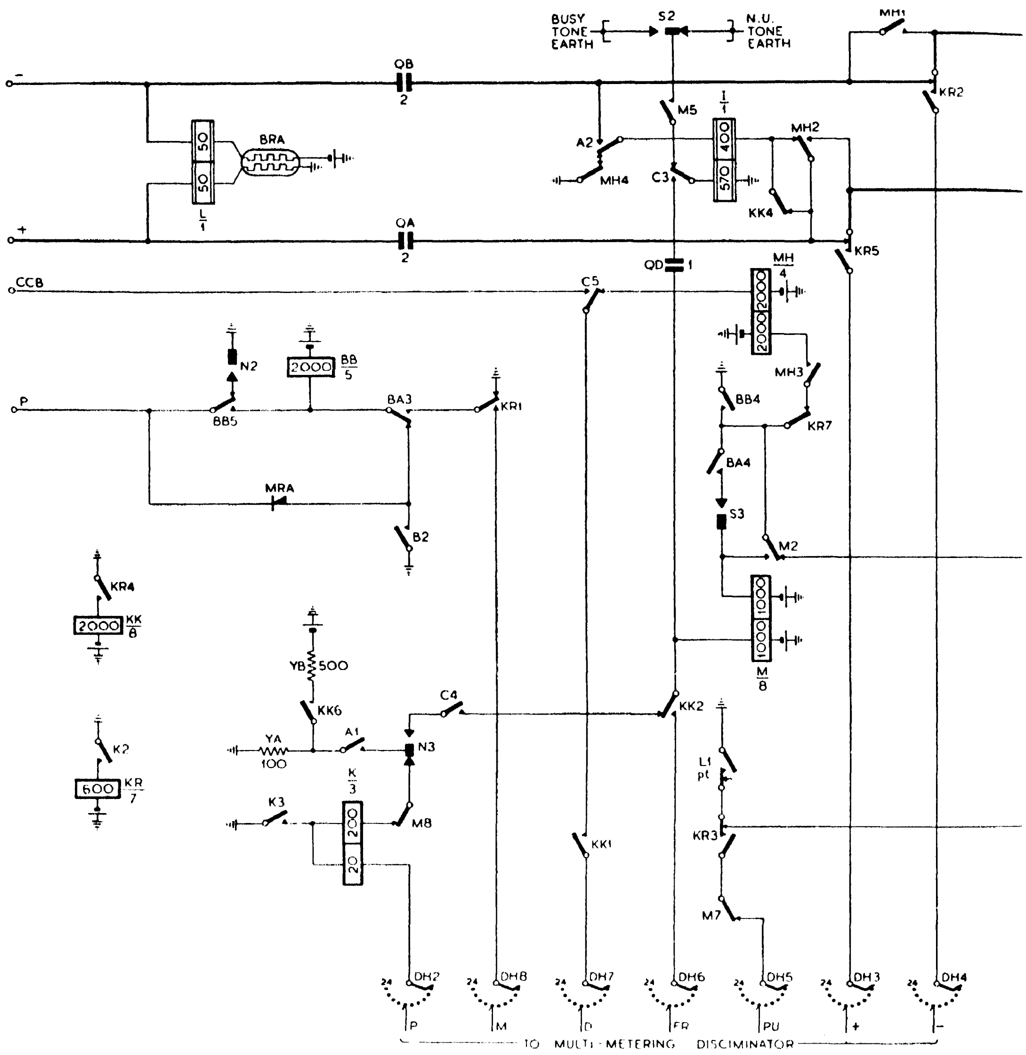
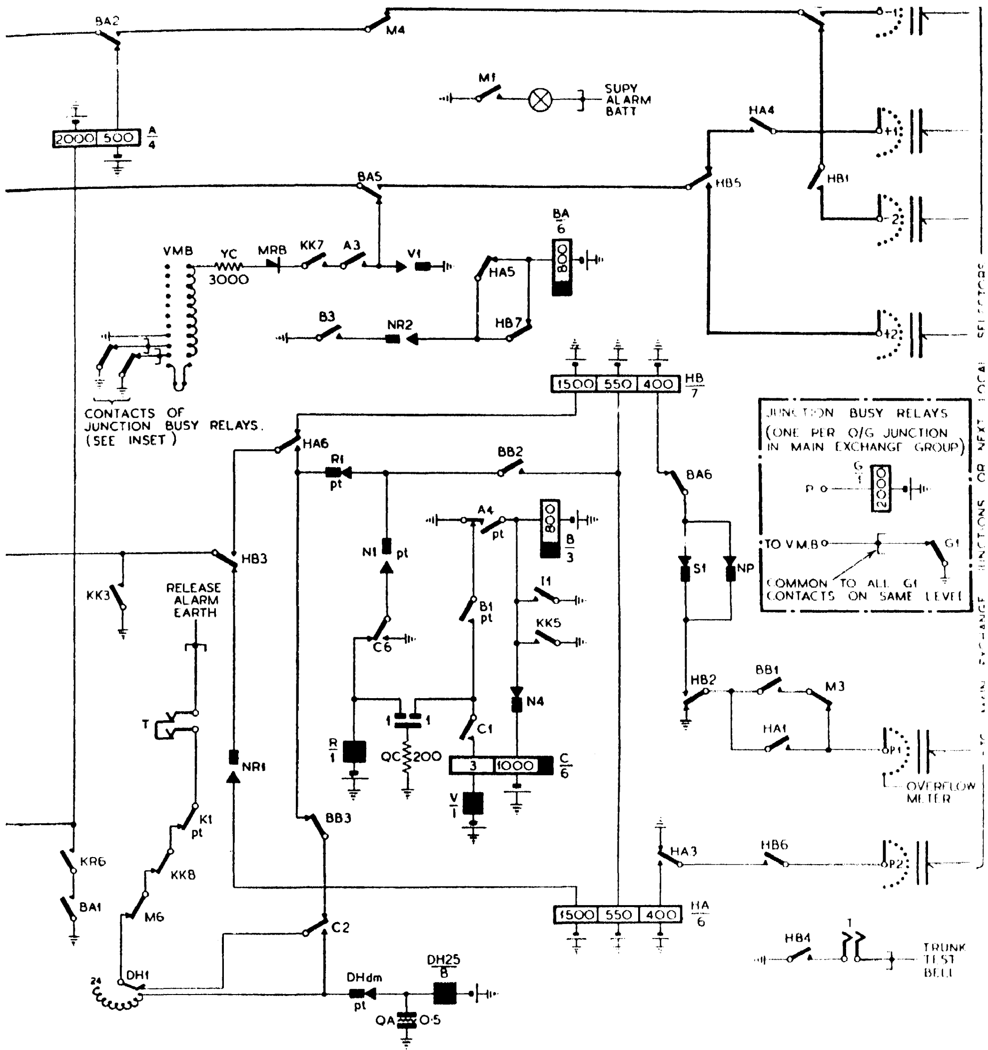


FIG. 379. SATELLITE

When a free outlet is seized, the *BA* relay operates, ***BA*2** and ***BA*5** extending the pulsing-out loop to the junction, whilst ***BA*1** provides a new holding circuit for the *A* relay. Contact ***BA*3** applies earth to the *M*-wire of the discriminator as an indication that a junction to the main exchange has been seized, and that pulsing out may now commence.

Multi-metering at Main Exchanges. We have seen in the previous sections how multiple fee metering can be incorporated in the discriminating equipment at a satellite exchange. The equipment required for fee determination and for the barring

The problem is somewhat different at main exchanges of a non-director network. Most of the calls originated from such exchanges are either local, i.e. on the main exchange itself, or to the satellite exchanges—a comparatively small pro-



Exchange 1st Selector

of calls to routes beyond the 15-mile radius of the exchange can be added to the equipment at a satellite exchange at reasonable cost. The basic requirement of all these facilities is in fact the provision of a means of counting the impulse trains dialled by the subscriber. If this equipment is provided for discrimination and digit absorption, it is readily adaptable to include the multi-metering and route restriction facilities.

portion of the traffic being to distant exchanges over multi-fee routes. In these circumstances it is clearly not economical to provide fee determination and route restricting equipment at the 1st selector stage where a very high percentage of the total traffic requires only single-fee metering. It is preferable that the multi-metering equipment should be located at a later switching stage where a higher proportion of the traffic is to the multi-fee area.

It has been shown that the standard practice in non-director areas is to apply the actual metering condition either from the final selector on local calls, or from the outgoing relay set on junction calls. If all outgoing junction traffic is to terminal exchanges, i.e. if the subscriber cannot dial through a distant exchange to some other exchange, then each outgoing route carries traffic only of one fixed fee. For example, if there is an outgoing route from exchange *A* to another exchange *B* 12 miles away, and it is not possible to dial through exchange *B* to any other exchange, then all calls leaving exchange *A* on this route have a uniform fee of 3 units. The outgoing (auto-auto) relay sets can be directly associated with each outgoing route and can make provision for the application of the appropriate number of meter pulses on all effective calls. This involves only a very small increase in the cost of the auto-auto relay sets, since there is no necessity for digit counting or fee determination circuits. The standard auto-auto relay set does, in fact, require very little modification to apply either 2, or 3, or 4 meter pulses instead of the usual single pulse when the called party replies. The circuit can be of a standard design with facilities for connecting the correct number of meter pulses to the relay set as required by the route on which the circuit is used. Such fixed-fee relay sets could also be placed in the trunks between selectors provided that all traffic routed through them requires a uniform charge.

An examination of a large number of practical cases has shown that a very high proportion of the total outgoing traffic from a non-director area is to exchanges accessible over direct routes. It has therefore been decided that, for the present, direct dialling by the subscriber shall be restricted to those exchanges within the 15-mile circle which can be reached over direct routes from the originating main exchange. This permits the use of simple multiple-fee registration from the auto-auto relay set, without the provision of elaborate and expensive fee determination equipment. It is the intention that the comparatively small amount of traffic to indirectly-connected exchanges will, for the time being, be dealt with by the automanual operator.

Irregular Access by Tandem Dialling. The simple multi-fee metering scheme described in the previous section has several inherent disabilities. If all outgoing routes are to terminal exchanges which have no other access to the telephone network, there are no complications. In practice, however, there are usually further outgoing routes from the objective exchange, and care must be taken with the trunking arrangements to prevent subscribers from obtaining irregular access to distant exchange areas by tandem dialling through the intermediate exchanges. At the same time it is often desirable to allow operators access on tandem switching routes which must be barred to automatic subscribers.

For purposes of illustration let it be assumed that exchange *A* (Fig. 380) is the main exchange of a multi-exchange area which also includes satellite exchanges *B* and *C*. Similarly, exchange *V* is the main exchange of another satellite area situated some twelve miles from exchange *A*. There are two satellites, *W* and *X*, working into exchange *V*. Exchange *G* is an independent non-director exchange with a direct route to *A*, whilst *Y* and *Z* are similar independent non-director exchanges working to *V*.

Exchange *V* is within the multi-fee metering range of the subscribers on *A*, and it is possible to give automatic access to *V* by the provision of 3-fee multi-metering relay sets on the outgoing junctions at *A*. If, as is usual, satellite exchanges *W* and *X* are trunked from 1st selector levels at *V*, then a calling subscriber at exchange *A* can obtain access to either of these satellites by dialling the appropriate first digit. There is no reason why access should not be given to satellite exchange *W* since this exchange is the same chargeable distance from *A* as exchange *V*. Satellite exchange *X*, on the other hand, is outside the 3-fee range of exchange *A* and, although a 4-unit fee is appropriate, the relay set at exchange *A* can record only a fixed 3-unit charge. If the outgoing junctions to exchange *X* are trunked direct from the 1st selector levels at *V*, then access to exchange *X* can be barred by disconnecting the appropriate level of the incoming 1st selectors of the *A–V* route. If the independent non-director exchanges *Y* and *Z* are also trunked from 1st selector levels, the same method can be employed to prevent any subscriber on exchange *A* obtaining irregular access to *Y* or *Z*.

The disconnexion of certain 1st selector levels may be satisfactory in circumstances where there is only one incoming route to be considered. In practice it is quite possible that there are routes incoming to exchange *V* from other non-director areas so located that exchange *X* is at the same chargeable distance as exchange *V*. Similarly, exchanges *Y* and *Z* may, for some incoming routes, be at the same chargeable distance as the main exchange *V*. Whilst it is quite practicable to disconnect one or more levels of *all* the incoming selectors at a particular exchange, it is not feasible to treat the 1st selectors of each incoming route

separately and to disconnect different levels from different groups of incoming selectors.

The problem can be simplified by preventing access to all outgoing routes except those to satellite exchanges—irrespective of the chargeable distance from the originating exchange. Thus, in Fig. 380 arrangements could be made for the 1st selector levels serving exchanges *Y* and *Z* to be disconnected on the banks of the incoming selectors associated with all incoming routes. At the same time all the incoming selectors would have access to every satellite exchange in the area. In any particular case the majority of these satellite exchanges would be at the same chargeable distance as the main exchange, but a few of the satellite exchanges (depending upon their location relative to the originating exchange) might be subject to a different call charge. One method of eliminating this discrepancy would be to arrange for all satellites in a multi-exchange area to carry the same charges as the main exchange of the area. If this is not possible, then the only alternative is to provide more or less complex impulse counting equipment at the originating exchange to bar access when the digits dialled by the calling subscriber relate to a satellite exchange which carries a charge different from that of the main route.

The volume of traffic to satellite exchanges of different call values is in most cases a comparatively small proportion of the total traffic on the route, and it may be more economical to lose revenue than to provide route discrimination equipment at the outgoing exchange. Where route restriction equipment is envisaged, it is generally preferable to trunk the satellite exchanges, as far as possible,

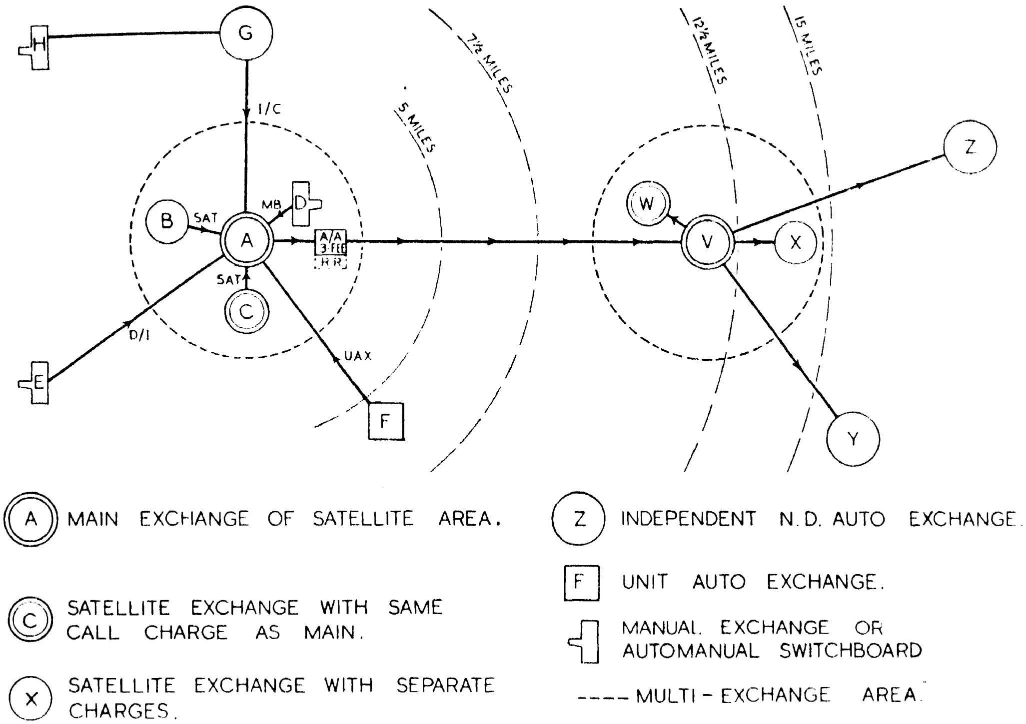


FIG. 380. ILLUSTRATING THE VARIOUS PROBLEMS OF MULTI-METERING IN A NON-DIRECTOR AREA

from the levels of 1st selectors and to allocate 2nd and 3rd selector levels to the routes outgoing from the multi-exchange area. By this means it is possible to obtain discrimination between satellites merely by counting the first impulse train. Moreover, if all the outgoing junction routes to independent exchanges are trunked (via 2nd and 3rd selectors) from one level of the 1st selectors, then it is necessary only to disconnect this one level from the banks of the incoming selectors.

In Fig. 380 two satellites, *B* and *C*, have been shown in the multi-exchange area served by exchange *A*. Satellite *C* carries the same call charges as the main exchange (*A*), and hence the subscribers on *C* are in exactly the same position as

the main exchange subscribers. It should be noted, however, that the appropriate charge is determined by the fee determination equipment in the discriminator circuit and not by the relay set on the outgoing route from the main exchange. Satellite *B* has a separate charge list, but the subscribers can be barred access to any predetermined dialling codes, and any appropriate fees can be arranged by suitable strappings in the discriminator circuit. Complications may arise, however, on satellites which have their own charge lists if route restriction equipment is provided in the outgoing relay sets on the main junction route. If, for example, the charge from satellite *B* to satellite *X* is 4 units, then, although the discriminator on the originating satellite can make provision for the correct charge, the call would be barred by the route restricting equipment on the outgoing junctions from the main exchange *A*. In any case it is difficult to provide such access, since this would involve separate dialling instructions for subscribers on satellite *B*. (When route restriction equipment is provided, then the main exchange subscribers would be instructed to dial "0" for calls to exchange *X*.) Difficulties such as these are a further argument in favour of making all satellite exchanges carry the same charges as the main exchange.

Route Restriction. Irregular access to exchanges by dialling through a distant switching centre can be prevented by the installation of equipment at the outgoing exchange which will count the digits dialled by the subscriber and prevent access if the code is irregular. Generally speaking, outgoing junction routes are trunked either from 1st or 2nd selector levels. If it is desired to permit access to one 1st selector level, but to bar access to another 1st selector level, then it is necessary to count only the first impulse train transmitted from a distant exchange. If, however, it is necessary to differentiate between junction routes terminating on 2nd selector levels, then it becomes necessary to count the first *two* trains of impulses transmitted over an outgoing junction.

If, for example, exchanges *W* and *X* are connected to levels 3 and 4 respectively of the 1st selectors at *V* (Fig. 380), then equipment is required on the outgoing junctions at *A* to permit the call if the first digit transmitted over the junction is 3, but to bar the call if this first digit is 4. If, on the other hand, exchanges *W* and *X* are routed from, say, the 5th and 6th levels of the group of 2nd selectors connected to 1st selector level 2, then differentiation must await the dialling of the second digit, i.e. to bar the call if the second digit is 6, but to allow the call to proceed if the second digit is 5.

Equipment has been designed to provide discrimination either on the first or second digit transmitted over an outgoing route. The equipment can be associated with the fixed-fee auto-auto relay set at the originating exchange. It is, however, the intention to fit this equipment only if there is evidence of an appreciable amount of fraudulent dialling.

Operator Access. So far no mention has been made of the traffic from manual exchanges or from the automanual switchboard (*D*) serving exchange *A*. Such calls do not require metering, and it is most desirable that the restrictions imposed to prevent irregular dialling by subscribers should not prevent tandem dialling by operators. Provided that impulsing and transmission are satisfactory, facilities should be provided for the automanual exchange (*D*) to dial through exchanges *A* and *V* in order to obtain access to *Y* and *Z*. Similarly, distant manual exchanges, such as *E*, with junctions to *A*, will normally require facilities to dial through the equipment at exchanges *A* and *V* to obtain distant centres such as *Y* and *Z*. There may also be other manual exchanges, such as *H*, with junctions to an independent non-director exchange *G*. The circuits from *G* to *A* must permit of tandem dialling facilities for the manual exchange operators, but at the same time must prevent such tandem dialling by the automatic subscribers on exchange *G*.

We have assumed that a 1st selector level at exchange *V*, which gives access to 2nd selectors serving exchanges *Y* and *Z*, is disconnected from the banks of the incoming selectors to prevent subscriber access. Facilities can be provided for manual board operators to dial through *V* to reach *Y* or *Z* if a separate group of junctions is provided between *A* and *V*. The second group could be arranged to give access to the level normally barred to calls on the first group. The disability of this method is the loss of efficiency due to the segregation of the junctions into two separate groups. The scheme does, moreover, require a separate route through exchange *A* in order to obtain access to the manual board group of junctions. As an alternative, a spare level of the 1st selectors at exchange *V* could be trunked to the 2nd selectors serving the outgoing routes (*Y* and *Z*). If exchanges *Y* and *Z* are served from 2nd selector levels normally trunked from level 8 of the 1st selectors at *V*, level 8 could be disconnected on the banks of the incoming selectors serving the *A*–*V* route. Subscribers on *V* exchange could obtain access to *Y* and *Z* by

the use of a 2-digit code 8_*, but subscribers on exchange *A* could not obtain access to these exchanges by dialling the code to obtain exchange *V* and then following this code by the 8_* code. If, say, level 1 of the incoming selectors at *V* is now connected to the 2nd selector group serving *Y* and *Z*, facilities are provided for the manual exchange operator to tandem dial from exchange *V* by dialling a 2-digit code 1_*. This method is dependent upon the fact that the subscribers at *A* do not know that access to *Y* and *Z* can be obtained via level 1.

Similar facilities can be provided on the incoming selectors at exchange *A* to prevent tandem calls by automatic subscribers on exchange *G*, but at the same time to permit access through exchange *A* for calls dialled by the manual exchange operator at *H*.

The provision of route restriction equipment at the originating exchange can also restrict the tandem dialling facilities available to the manual exchange operator. If, for example, in Fig. 380 route restriction equipment is provided on the outgoing route at *A* to prevent access to the distant satellite exchange *X*, it is impossible for any manual exchange operator to dial through this equipment to obtain exchange *X*. The difficulty can be overcome by providing separate groups of selectors in exchange *A* which give access to the junction routes on the *line* side of the route restriction equipment. On dialling-in and incoming routes this requires separate auto-auto relay sets to provide the holding conditions necessary for the selectors at exchange *A*, but on calls from the automanual board the holding conditions are provided by the outgoing termination at the switchboard.

Exchange *F* is a small rural automatic exchange dependent upon exchange *A* for all outgoing calls. Fee determination and route restriction equipment is normally provided at such exchanges, and arrangements can be made locally to assess the fee appropriate to all calls within a radius of 15 miles, and to bar access if any other exchange code is dialled. Exchange *Y* is assumed to be within 3-unit range of exchange *F*, but exchange *Z* is more than 15 miles distant and is to be barred. These facilities can be obtained by providing access at exchange *A* to the dialling codes used by the various manual exchange operators to obtain access to exchange *Y* (e.g. the dialling code given to the subscribers on exchange *F* would provide for the routing of the call via level 1 of the 1st selectors at *V*). Access to exchange *Z* is prevented by the operation of the route restriction equipment at exchange *F*.

In some cases it may be desirable to provide direct routes from exchange *A* to certain exchanges beyond 15 miles range in order to provide facilities for the manual exchange operators. These routes would not be accessible to the automatic subscribers at exchange *A* but, if the terminal exchange is within the multi-metering range of any U.A.X. dependent upon *A*, then the U.A.X. can be given access to these special routes.

Typical Trunking of Multi-fee Routes. The introduction of multi-metering facilities in a non-director area requires the allocation of a large number of dialling codes so that the subscriber can obtain access to all directly-connected exchanges within the 15-mile circle. Wherever possible the codes are made to conform to a standard system of allocations.

Fig. 381 shows a typical trunking diagram which has been simplified by the omission of the local selectors. Generally speaking, level 8 of the 1st selectors is reserved for giving access to the multi-fee area, but in areas where this level is already in use for the subscribers' numbering range, any other convenient 1st selector level (except 1, 9, and 0) may be allocated for multi-metering. In the typical arrangement shown, the 1st selectors are divided into six separate groups serving:

Coin-box subscribers (C.B.) on the main exchange.

Ordinary subscribers (Ord.) on the same exchange.

Satellite Exchange (Sat.) subscribers.

Small Unit Automatic Exchanges (U.A.X.) which require tandem dialling facilities.

Incoming routes from distant automatic exchanges (I/C). (These routes may carry traffic both from subscribers and from distant manual exchange operators.)

Incoming routes direct from manual exchanges (D/I).

Three separate groups of 2nd selectors are trunked from level 8. The first group serves the coin-box subscribers, the second group serves the ordinary subscribers on the main exchange, the subscribers on satellite exchanges and U.A.X.s. The third group serves the dialling-in operators. In addition there is a separate group of level 8 2nd selectors accessible from the automanual switchboard.

Levels 3, 4, 5, and 6 of the 2nd selectors are trunked to 3rd selectors. The dialling codes are so allocated that the 83 level serves only exchanges within the 1-unit fee area, the 84 level serves only those exchanges within the 2-unit fee area, whilst the 85 and 86 levels serve exchanges in the 3-unit

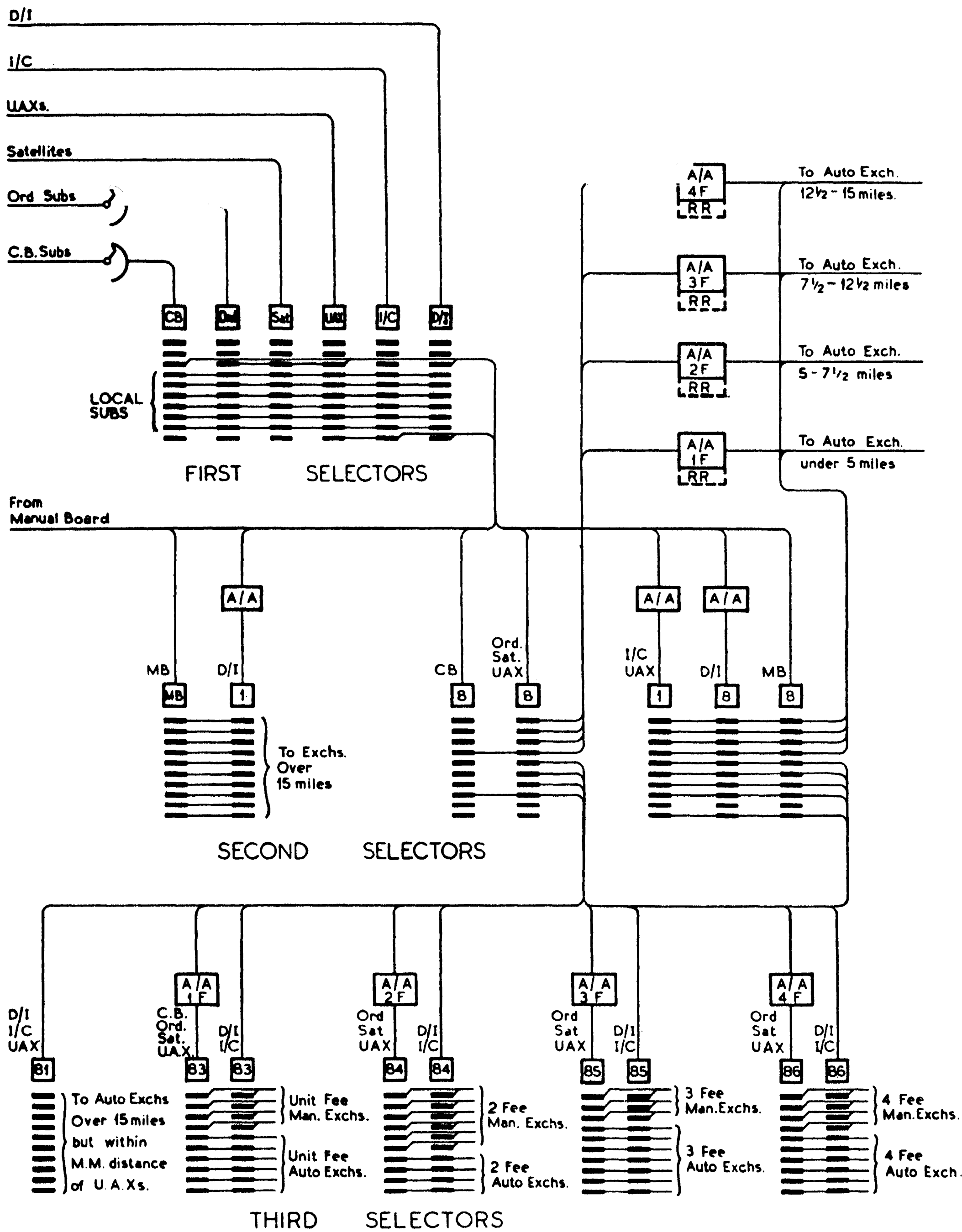


Fig. 381. Trunking Arrangements of Multi-fee Routes (Non-director Main Exchange)

fee and 4-unit fee areas respectively. The remaining levels of the 2nd selectors are available for direct outgoing routes. As far as possible, 2-digit dialling codes (87, 88, etc.) are used to give access to routes where there is a high volume of traffic, whilst the 3-digit codes (831, 841, etc.) are allocated to the smaller outgoing junction groups.

The coin-box group of 2nd selectors is given access only to the 3rd selectors serving unit fee routes (the 83 level), and to any other 2nd selector levels which give access to exchanges within the 5-mile radius (e.g. 87). On all calls to exchanges outside the 5-mile circle the coin-box user dials "0."

The 2nd selectors serving the automanual board and dialling-in operators have a common multiple to the 3rd selectors and to the exchanges directly connected to the 2nd selector levels. On calls from the automanual board, the necessary holding conditions are provided by the manual board relay set, whilst on incoming calls from distant manual exchanges the holding conditions are provided by a relay set connected between the 1st and 2nd selectors. This is a standard auto-auto relay set without metering facilities, and is provided with a continuous *P*-wire so that it can hold the 1st selector backward, and the 2nd (and possibly 3rd) selector forward.

The levels of 2nd selectors serving ordinary subscribers (multi-exchange area and U.A.X.'s) are trunked out to direct junctions or to separate groups of 3rd selectors. On calls routed over junctions connected to 2nd selector levels the holding conditions are provided by auto-auto relay sets connected between the 2nd selector banks and the outgoing junctions. These relay sets are required to give metering conditions and are connected to register the appropriate fee depending upon the length of the junction served. Route restriction equipment can be associated with these outgoing relay sets if necessary.

On calls routed via 3rd selectors, the holding conditions are provided by similar fixed-fee multi-metering relay sets inserted in the trunks between the 2nd selectors and the 3rd selectors. This arrangement is possible only when each 3rd selector group serves routes of the same chargeable distance (i.e. all 2-unit routes from level 84, etc.). This arrangement has some economic advantages in that the links between the 2nd and 3rd selectors carry a higher traffic per circuit than the individual outgoing junctions from the 3rd selector levels. Fixed-fee auto-auto relay sets between the 2nd and 3rd selectors can be provided with route restriction equipment, but it should be noted that, since this equipment makes provision for the counting of two digits only (and one digit is absorbed by the 3rd selector), the effective discrimination is restricted to one digit.

The subdivision of each 3rd selector group into two parts is necessary in order to provide two separate groups of junctions to manual exchanges. The calls over such routes may originate either from operators or from automatic subscribers. If the call is from an operator it is desirable that the standard supervisory conditions should be returned when the distant manual exchange answers. If a common group of junctions were provided to serve both operators and automatic subscribers, then this answering condition would cause premature operation of the meter on calls from an automatic subscriber. By providing two separate groups of circuits, one group can be arranged to give the supervisory condition when the distant exchange operator replies, and the other group can provide "guarded metering" conditions, i.e. deferment of the metering condition until the called subscriber replies.

No access is provided from the 8th level of the 1st selectors serving routes incoming from distant automatic exchanges. This is necessary to prevent distant automatic subscribers from dialling through the exchange to obtain access to the various routes accessible from the 8-level selectors. (Route restriction equipment may not be fitted at the originating exchange.) The same incoming routes may, however, be used by distant manual operators who may be permitted access to the various outgoing routes normally trunked from level 8. To provide access to the operators, but at the same time to bar the service to automatic subscribers, level 1 is taken out to a group of 2nd selectors which have access to the same outgoing routes as the 8th level 2nd selectors serving the dialling-in operators and the automanual exchange.

Level 1 of this group of 2nd selectors is trunked to a special group of 3rd selectors which gives access to a maximum of 10 automatic exchanges which are outside the 15-mile range of the main exchange but are within multi-metering range of some of the U.A.X.s parented on this main exchange. Some of the routes from this level may be outside the dailling range of certain of the U.A.X.s, but in such cases discrimination is effected by the route restricting equipment at the originating exchange.

Level 1 of the 1st selectors serving the dialling-in routes is also trunked out to a separate group of 2nd selectors which serves exchanges which are accessible only to the automanual board and dialling-in operators.

Auto-auto Relay Set with Multi-metering Facilities. The upper part of Fig. 382 shows an auto-auto relay set which provides fixed-fee multi-metering facilities. The relay sets on any given route can be arranged to give either 1, 2, 3, or 4 unit fee metering, but the circuit does not give meter discrimination, i.e. all calls on the route must have the same fee. The lower part of Fig. 382 shows a route restricting equipment which can be used (if required) in conjunction with the auto-auto relay set to bar the route to certain classes of call.

The auto-auto relay set is seized by the loop extended from preceding selectors. This causes the operation of relays, *A*, *B*, and *BA* in order to seize the selector at the distant end and to provide the necessary holding and guarding conditions in the local exchange. Contact ***BA*3** seizes the route restricting equipment (when fitted) over the *H*-wire, whilst ***BA*2** completes a circuit for relay *MD*.

Relay *A* responds to the impulses from the calling subscriber and, at the first break, *A*1 operates relay *C*. This same contact (*A*1) repeats the impulses over the *PU*-wire to the route restricting equipment. *A*2 repeats the impulses to the junction. During the impulse train, contact **C1** short-circuits relays *D* and *I* to provide a non-inductive impulsing loop. **C2** operates the relief relay *CA*. At the end of the impulse train, *C* falls away and at *C*1 removes the short circuit from the bridge relays (an 800 Ω shunt still being maintained at this stage). *C*2 disconnects *CA* and at the same time applies earth to the *CN*-wire of the route restricting equipment to operate the discriminating relays in the latter. After the release lag of *CA*, *CA*3 disconnects the 800 Ω shunt from relays *D* and *I* to restore the forward loop to normal. (This is the two-stage drop-back feature described in earlier chapters.)

When the called subscriber answers, the reversal of the current in the junction loop permits relay *D* to operate, and **D1** releases *MD*. *MD*2 now operates relay *DD*, and contacts **DD1** and **DD4** prepare the circuit for the operation of relay *DA* to the first *S* pulse. **DD2** and **DD3** effect the usual reversal backwards, whilst **DD5** disconnects *MD*. The first *S* pulse operates relay *DA* on its 1500 Ω winding, and the contacts of *DA* prepare the metering condition in readiness for the operation of relay *DB* to the succeeding *Z* pulse. The *Z* pulse completes the circuit for *DB* and, at the same time, holds *DA*. During the *Z* pulse, relay *MP* responds to the predetermined number of meter pulses. At the end of the *Z* pulse, *DA* releases, and at *DA*1 disconnects *MP*.

The circuit is now established for conversation, and in due course, when the called subscriber clears, relay *D* releases. *D*1 disconnects *DD*, and *DD*5 operates *MD*.

When the calling subscriber replaces his receiver, the release of *A*1 operates relay *C* and disconnects relay *B*. *A*2 breaks the holding loop on the outgoing junction. The operation of **C2** completes the circuit for relay *CA*. The release of *B* disconnects the earth from the incoming *P*-wire to release the preceding selectors and relay *BA*. *B*1 also releases relay *C*. When *BA*1 restores, earth is re-connected to the incoming *P*-wire, and *BA*5 now releases relay *DB*. *BA*2 applies earth via **DB4** to operate the "effective calls meter." The restoration of *C* releases *MD*, and *MD* in turn releases *CA*. *CA*1 and *CA*2 finally remove the engaging earth from the incoming and outgoing *P*-wires.

To summarize, the circuit is so arranged that, when the calling subscriber clears, earth is maintained on the incoming *P*-wire until relay *B* has released, the earth then being disconnected to allow preceding selectors to release. After the release lag of relay *BA* (say, 30 to 45 msec), an earth is re-connected to the incoming *P*-wire to guard the outgoing junction and relay set. This guard is of sufficient duration to ensure that the selectors at distant exchanges will release before the circuit can be re-seized for another call. The guard is maintained until all relays in the outgoing relay set have restored to normal. It should be noted that the outgoing *P*-wire is guarded during the entire release period, i.e. there is no intermediate period of disconnexion as on the incoming *P*-wire.

Conditions sometimes arise where the calling subscriber clears during the busy flash period. In these circumstances relay *MP* operates to the battery on the positive wire. This delays the release of the circuit until the end of the flash period, to provide an adequate guard against the seizure of the distant exchange equipment. (The guard is provided in this case by the release lags of relays *MP*, *MD*, and *CA*.)

The route restricting equipment accepts impulses repeated to it from the *A*1 contact of the auto-auto relay set. The impulse trains are counted on the uniselector *MM*, the banks of which are strapped to operate relays *MA*, *MB*, *MC*, or *MD* as required. Discrimination can be effected on either the first or second digit. If a call is to be barred, N.U. tone is transmitted to the calling party, and the equipment on the outgoing side of the auto-auto relay set is released. The circuit provides for the guarding of the incoming *P*-wire to prevent

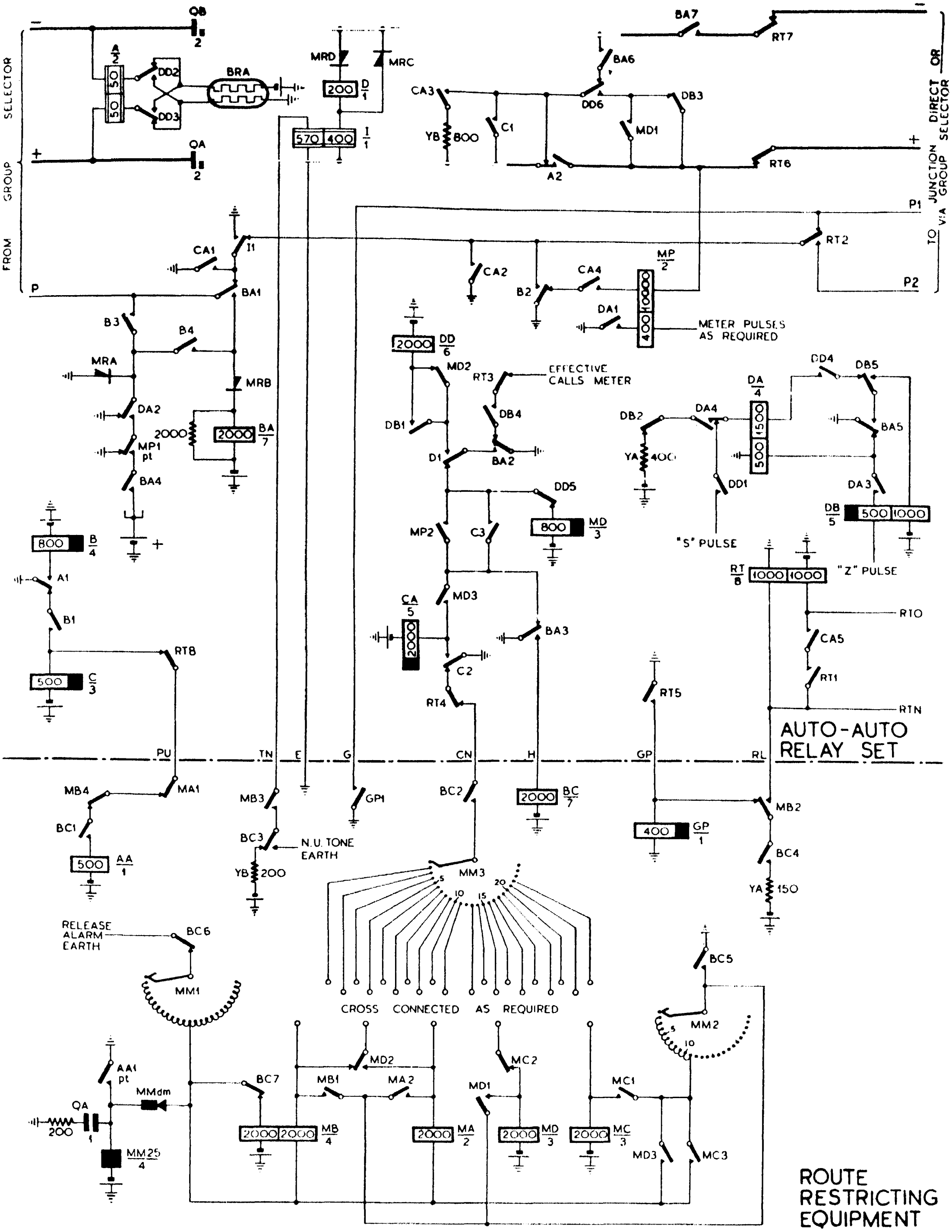


Fig. 382. Auto-auto Relay Set with Multi-metering Facilities

re-seizure of the auto-auto relay set whilst the *MM* uniselector is homing.

Receipt of the first digit positions the wipers of the uniselector on one of the contacts 2 to 11. During the interdigital pause which follows, one of the relays *MA*, *MB*, *MC*, or *MD* is operated to the earth on the *CN*-wire. The relays are operated to give the following conditions:

Operation of relay MA indicates that the call is allowable and that it is unnecessary to consider the next digit. If this relay operates, the *P*-wire is disconnected by ***MA*1** to prevent further impulsing.

Operation of relay MB indicates that the call is to be barred and that it is unnecessary to consider the next digit. N.U. tone is, in this case, transmitted over the *TN*-wire by the operation of contact **MB3**. **MB2** releases relay *GP* and applies battery to the *RL*-wire to operate relay *RT* in the auto-auto relay set. The contacts of the latter disconnect the outgoing side of the circuit to release the junction and any succeeding equipment. A release guard is provided by the slow release feature of relay *GP*.

Operation of relay MC or relay MD indicates that discrimination cannot be effected until a second digit has been received. The operation of either of these two relays causes the uniselector to hunt automatically to contact 12 and the equipment is ready to receive the second digit. The second digit positions the wipers on one of the contacts 13 to 22 and, during the succeeding interdigital pause, either relay *MA* or relay *MB* is operated. These two relays function in the manner already described to permit or bar a call as desired.

The route restriction equipment is retained in service until the associated auto-auto relay set is released at the end of a call. The release of relay *BC* now permits the uniselector to drive to its home contact. During the homing period, *MB* is operated to provide a release guard.

Auto-auto Relay Set with Impulse Regenerator. Fig. 383 shows an auto-auto relay set suitable for use at a tandem switching point (e.g. in front of the D/I level 8 group of 2nd selectors in Fig. 381). No metering facilities are provided but the circuit includes a mechanical impulse regenerator for the storage of the incoming impulse trains and their subsequent re-transmission at the standard frequency and ratio.

As before, relay *A* operates to the calling subscriber's loop and at ***A*1** operates *B*. ***B*1** guards the circuit against intrusion, whilst ***B*2** prepares the circuit for impulsing by operating relay *BB*. The *A*1 contact repeats the incoming pulses to the impulse regenerator *R* magnet. Relay *C* operates to the first break impulse and retains during the impulse train due to the short circuit across its winding.

The operation of relay *C* energizes the *M* magnet of the regenerator (at ***C*1**) to enable the storage of the incoming pulses to be effected. ***C*2** short-circuits the *D* and *I* loop during impulsing in order to maintain uniform impulsing conditions for relay *A*. ***C*3** completes the circuit for relay *IP*, whilst ***IP*1** operates relay *IS*. ***IP*2** prepares the pulsing-out loop. The operation of ***IS*1** operates relay *MD*, and ***IS*4** disconnects the *T* magnet circuit to prevent premature energization.

At the end of the incoming impulse train, relay *C* restores, and at *C*1 releases the *M* magnet to mark the digit on the code pins of the regenerator. The closure of the *Mdm* springs completes a circuit for the operation of relay *BY*, which now locks via its own contact (***BY*6**) to the ***N*** spring earth. (It will be recalled that the *N* springs close immediately on the first release of the *R* magnet.) Contacts ***BY*1** and ***BY*2** complete the pulsing-out loop, whilst ***BY*3** allows relays *IP* and *IS* to release in turn. (*IP* has a release lag of some 350 msec, and *IS* has a lag of some 250 msec.)

The *T* magnet now operates and, with the ***Tdm*** springs broken, relay *MD* restores after a delay period of some 250 msec. Relay *IP* now re-operates and in turn completes the circuit for *IS*. ***IS*4** releases the *T* magnet, thereby causing the sending mechanism of the regenerator to pulse out. The impulses are transmitted until a marked pin *S* is reached, when relay *MD* re-operates. If any further trains of impulses are stored in the regenerator, the *N* springs remain off-normal, and the same sequence is repeated (i.e. until the *N* springs open and release relay *BY*). The release of *BY* removes the pulsing-out loop and restores the transmission conditions. *IP* also releases, but relay *IS* is now held by relay *I* which, in turn, is held by the current in the forward junction loop. The sum of the release lags and the operate lags of relays *MD*, *IP*, and *IS* provide the interdigit pause for the re-transmitted trains of impulses. This pause is of the order of 800 msec.

When the called subscriber answers, the reversal of line current energizes relay *D*, and ***D*1** releases *MD*. The restoration of *MD*3 completes the circuit for *DA*. Relay *DA* is provided to give an alternative circuit for relay *MD* in order to maintain a flashing sequence by making *DD* dependent upon *MD* as well as *D*. The *DA* relay also disconnects the *R* magnet to prevent false storage in the regenerator on clear down or when *DD* reverses the current in the incoming loop. In addition,

*DA*4 completes a circuit for the operation of relay *DD* which, at **DD1** and **DD2**, gives the normal supervisory reversal.

If the called subscriber flashes during the conversational period, relay *D* releases. *D*1 releases relay *DD* and re-operates relay *MD*. Relay *DD* cannot now be re-operated until the slow-release relay *MD* has fully restored.

released whilst digits are stored in the regenerator. Under these circumstances relays *B* and *BB* release but, after the restoration of *BB*3, a guard is re-applied to the *P*-wire by relay *BY* until the regenerator has transmitted the stored digits.

In all circuits of this type, there is the possibility of a momentary release of the *A* relay due to current surges during the seizure of the circuit.

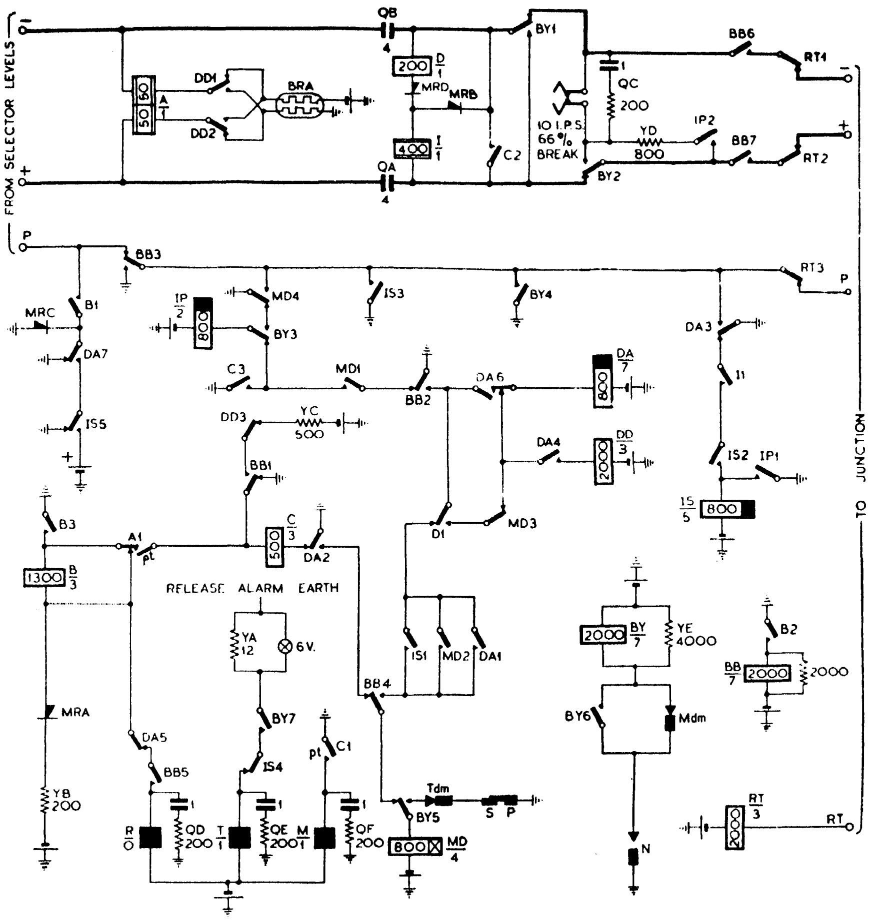


FIG. 383. AUTO-AUTO RELAY SET WITH IMPULSE REGENERATOR

At the end of the call, the release of relay *A* restores relays *B* and *BB*. During the release of the latter, the incoming *P*-wire is disconnected for some 20–30 msec to release the preceding selectors. Relay *DA* is released at *BB*2, and during its slow-release period *MD* is energized from the earth at *DA*2. **MD1** operates *IP*, and **IP1** in turn operates *IS*. The *P*-wire is therefore earthed continuously for a period equal to the release lags of *MD*, *IP*, and *IS* to guard the junction.

Under certain conditions, the relay set can be

Unless care is taken in the design of the circuit, there is a danger of such a short pulse energizing the *R* magnet of the regenerator, but the *C* relay may not be energized for a sufficiently long period to complete the marking operation. This "flick" operation of the **C1** contact may, under certain conditions, produce a mechanical lock-up. The danger is minimized in Fig. 383 by the use of a *C* relay with an ordinary fast coil, the required release lag being obtained by short-circuiting the winding. There is also a possibility of a short

transient operation of the A relay due, for example, to the momentary looping of the line by bridging wipers of the preceding selector. This again can produce a mechanical lock-up which can often only be removed by the manual re-setting of the marking magnet. This danger is eliminated by providing an additional relay (BB) as a relief on B. The $BB5$ contact in the receiving magnet lead prevents the energization of the magnet if the A relay is not energized sufficiently long for both

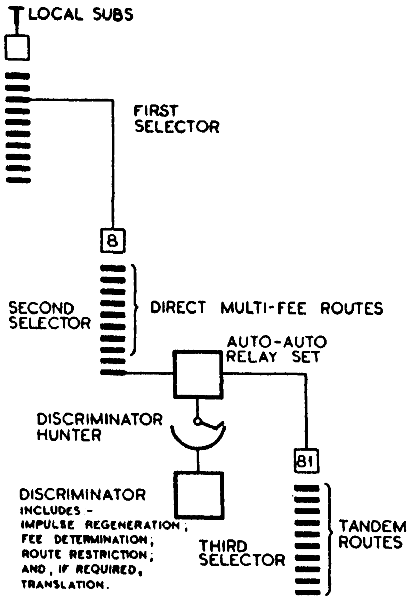


FIG. 384. METHOD OF OBTAINING TANDEM DIALLING AT A NON-DIRECTOR EXCHANGE

relays B and BB to operate. If the pulse is sufficiently long to operate both relays B and BB, the B relay will be more or less fully energized so that, when $A1$ releases, the pulse of current to the R magnet will be substantially equal to the release lag of the B relay. Under these conditions also the C relay operates quickly (immediately the $A1$ contacts restore) and does not release until $BB1$ restores. This ensures that the correct sequence of the R magnet releasing before the M magnet is obtained.

Tandem Dialling. It has been stated in previous paragraphs that a high percentage of the total outgoing traffic from a non-director area is to directly-connected exchanges. The much smaller volume of subscribers' traffic which requires tandem dialling through a distant centre can usually be handled satisfactorily at the auto-manual board. It is possible that, in the comparatively near future, equipment will be developed to permit of tandem dialling by subscribers in circumstances where this can be justified. Fig. 384 shows a typical trunking scheme for tandem dialling.

We have seen (Fig. 381) that all the outgoing routes from a non-director main exchange are trunked either directly from the 2nd selectors connected to level 8, or indirectly via 3rd selectors connected to levels 83, 84, 85, or 86. Level 1 of the 8th group of 2nd selectors serving automatic subscribers has been reserved for tandem dialling codes. Third selectors are now connected to level 81, and the levels of these selectors give access to the various outgoing routes to tandem switching centres. (Where a tandem switching centre is also a directly-connected exchange, the outgoing trunks from level 81_* can be commoned to the 2nd or 3rd selector trunks serving the direct route.) A special auto-auto relay set is inserted between level 1 of the 2nd selectors and the 3rd selectors. This relay set is provided with a uniselector which serves as a hunter to seize a discriminator circuit whenever a call is originated. The discriminator circuit includes impulse counting elements in order to provide fee determination and route restriction facilities. The circuit also includes impulse regeneration to increase the number of links over which tandem dialling is possible.

With this trunking scheme three digits are required to route the call to the selected tandem switching centre. One or two additional digits may then be required to extend the call to the objective exchange. This means that a total of four to five impulse trains may be required on calls routed through one tandem switching centre. In some cases it may be necessary to pass certain calls through two tandem switching points (with impulse regeneration at each tandem exchange). The question therefore arises as to whether or not translation facilities may be desirable in order to minimize the number of digits to be dialled by the subscriber. Translation equipment can readily be incorporated in the discriminator circuit. If a 3-digit code is dialled by the calling subscriber, the first two digits are required to position the 1st and 2nd selectors, and the third digit is passed into the discriminator. Thus with 3-digit codes the discriminator can provide a theoretical maximum of ten translations. If a 4-digit code is used, then the two final digits can be passed to the discriminator to give a maximum of 100 different routings. It is unlikely that a greater number of translations will be required at a non-director exchange.

EXERCISES XII

1. A subscriber on the central exchange of a non-director area dials 74237, and obtains thereby a subscriber at a 500-line satellite exchange in the area. Draw a simplified trunking diagram to show the selectors and relay sets that may be involved in the connexion, and the positions of main and intermediate distribution frames. Explain how an intermediate distribution frame is used (*a*) with subscribers' uniselectors, and (*b*) with linefinders. (*C. & G. Telephony, Grade II*, 1946.)

2. In a certain telephone area the average busy hour traffic from the main exchange to a particular satellite exchange is 8 traffic units. To carry this traffic 20 junctions are provided from a 4-group grading of the outlets from a selector level having an availability of 10, the first two choices in the grading being on an "individual" basis. The traffic is evenly distributed among the four groups in the grading, and the grade of service afforded is 0·002 approximately. The junctions are routed to the satellite exchange in two cables, *A* and *B*, the 8 junctions associated with the first two choices in the grading being in cable *A*, and the other 12 junctions in cable *B*. What would be the immediate effect on the grade of service if cable *B* were destroyed, assuming that the traffic flow remained constant, and what improvement could be made in the grade of service by using the remaining 8 junctions, in cable *A*, to the best advantage? (*C. & G. Telephony, Grade III*, 1943.)

3. Enumerate the functions of a discriminating selector. Explain, with the aid of a trunking diagram, and assuming a suitable subscribers' numbering scheme, how economies in switching plant and junction lines may be effected by the use of discriminating selectors at a satellite exchange in a non-director area. (*C. & G. Telephony, Grade II*, 1942.)

4. The subscribers' numbers allotted to a discriminating satellite exchange in a non-director area are 61100 to 61799. Describe, with reference to a diagram, the operation of suitable discriminating circuit elements for this exchange. (*C. & G. Telephony, Grade II*, 1943.)

5. A non-director area is to be served by a main automatic exchange and three satellite exchanges. State the objections to the following allotment of subscribers' telephone numbers, and suggest modifications which would remove these objections, giving due attention to economy in junction lines.

Main Exchange .	3000 lines	2000 to 4999
Satellite *A* . .	1500 lines	5000 to 5999
		6000 to 6499
Satellite *B* . .	1000 lines	7000 to 7999
Satellite *C* . .	1000 lines	8000 to 8999

(*C. & G. Telephony, Grade II*, 1944.)

6. Give a concise description, illustrated by simplified trunking diagrams, of trunking arrangements suitable for a network comprising a main exchange and two discriminating satellite exchanges, the subscribers' multiple capacities of the exchanges being as follows:

Main Exchange .	6000 lines
Satellite *A* . .	800 lines
Satellite *B* . .	1200 lines

Indicate on your diagram a suitable subscribers' numbering scheme for each exchange.

Explain how "local discrimination" facilitates the adoption of such a numbering scheme. (*C. & G. Telephone Exchange Systems II*, 1948.)

7. Show how the discriminator at a satellite exchange determines the apppropriate fee on a call to an automatic exchange outside the multi-exchange area.

8. Discuss the various alternative methods of obtaining multi-fee metering at a non-director main exchange. Illustrate your answer with a suitable trunking diagram which makes provision for traffic from dialling-in operators and satellite exchange subscribers.

9. It is required to provide automatic registration of calls up to four unit fees at a non-director main exchange, by incorporating the multi-metering facility in a relay set which would also function as an auto-auto impulse repeater. The relay set should also be suitable for working between ranks of selectors at the main exchange. It may be assumed that the number of unit fees given by the relay set would be predetermined by suitable "strapping" wires and that a machine giving 1, 2, 3, or 4 metering pulses would be available.

Outline the circuit design of the relay set you would propose for the purpose. (*C. & G. Telephony, Grade III*, 1947.)

10. The exchanges represented by *A*, *B*, and *C* are 2 miles apart, and the tandem exchange *T* is at the exact centre of the group of three. If exchanges *A* and *B* each originate 0·9 traffic unit in the busy hour to exchange *C*, calculate the total

mileage of junctions required under each of the three trunking schemes below:

(*a*) Direct routing of all traffic from A to C, and B to C.

(*b*) Indirect routing of all traffic from A to B, via T, to C.

(*c*) One direct junction from A to C, and one from B to C, with tandem routing for the surplus traffic to C.

Assume that pure chance traffic is offered on route T to C, as well as on the direct routes, and that the grade of service at each switching stage is to be the same. The following table should be used for the determination of the number of junctions required:

Traffic offered	0·25	0·53	0·90	1·32	1·80	2·31 T.U.
Number of junctions .	3	4	5	6	7	8

(*C. & G. Telephony, Grade III*, 1946.)

CHAPTER XIII

THE DIRECTOR SYSTEM

THE telephone requirements of a small town can often be met by the provision of a single exchange —normally located near the centre of the area to be served. In somewhat larger towns it is usually more economical to divide the automatic switching equipment into a "main" exchange and a number of "satellite" exchanges. The main exchange accommodates the subscribers in the central area of the town and also acts as a through switching centre for calls to and from the satellite exchanges. By the use of discriminating selectors at the satellite exchanges, it is possible to differentiate between purely local calls and calls which are to be routed via the main exchange, whilst digit absorption facilities permit the most economical use to be made of the satellite selector levels. The main feature of this non-director system is a common numbering scheme for all subscribers, i.e. a subscriber dials the same numerical digits to obtain access to a particular line whether the call is dialled from the main exchange or from any of the satellite exchanges in the network. Calls to exchanges within the multi-metering range, but outside the satellite area, are obtained by the use of special dialling codes.

A typical non-director area is illustrated in Fig. 385. The main exchange (Derby) makes provision for some 4000 lines, whilst the four satellites (Allestree, Spondon, Alvaston, and Mickleover) together serve a further 1500 subscribers on the fringes of the town. By the use of 2-digit dialling codes it is possible for any subscriber in the satellite area to obtain access to some 14 exchanges within a 15-mile circle of the centre. The main characteristics of such an area are:

(*a*) A very high percentage of the traffic originated at each satellite exchange is either local (i.e. to subscribers on the same satellite), or to the business centre of the town served by the main exchange.

(*b*) The traffic from any one satellite exchange to other satellite exchanges is generally insufficient to justify direct routes. (Provision is made in the design of the satellite exchange circuits to permit a limited number of satellite-to-satellite routes direct from the levels of the satellite 1st selectors. One such route is shown in Fig. 385 between Spondon and Alvaston.)

(*c*) Only a very small proportion of the total traffic originated in the multi-exchange area is to exchanges outside the linked numbering scheme.

(*d*) Outside a radius of some 3–5 miles from the centre of the town, the population is segregated into a number of distinct communities, i.e. villages and smaller towns. There is therefore no difficulty if subscribers in the multi-exchange area are instructed to dial a special code for the small percentage of calls to these surrounding exchanges.

(*e*) The total number of exchanges within the 15-mile circle from the centre of the town is comparatively small, so that a reasonable number of dialling codes will suffice to give full access to these exchanges.

The Characteristics of Telephone Traffic in a Large City. A large city—especially one with a high telephone density—presents a much more complex problem to the telephone switching engineer. The traffic in such a city differs materially, both in volume and character, from that of the non-director area. The difference is indicated clearly in Fig. 386, which shows the exchanges and junction network of Glasgow City, and should be compared with the typical example of a non-director area given in Fig. 385. In a circle of 7 miles radius from the centre of the city there are not less than 35 telephone exchanges (several of two units) with a complex system of direct junctions between exchanges. Of these exchanges 11 are within a radius of 2 miles from the centre.

The London Telephone Area is so complex that it is difficult to show the exchanges and junction routes on any diagram of reasonable dimensions. In Greater London (i.e. within 20 miles of Oxford Circus) there are some 237 telephone exchanges. Of these exchanges 75 are within 5 miles radius of Oxford Circus, and a further 65 fall within the belt 5–10 miles. Not only are there very many more exchanges in the large cities, but the *capacity* of each exchange is usually much greater than in the smaller provincial town.

The main characteristics of a large city area may be summarized as follows:

(*a*) A comparatively small proportion of the total traffic originated at any one exchange is to subscribers on the same exchange—the outgoing junction traffic may, in fact, represent from 70 to 80 per cent of the total originated traffic.

(*b*) The outgoing traffic from each exchange is

not concentrated on one main route (as the satellite to main exchange in a non-director area), but is more evenly distributed to a number of exchanges in the area.

(*c*) The volume of traffic between exchanges justifies a large number of direct routes. As the intensity of traffic to any particular destination increases, there is less and less to be gained by combining this traffic with other traffic over the same group of junctions. As the volume of traffic increases, the cost of the switching equipment required to segregate such combined traffic exceeds the savings in line plant. The economic justification for direct routes is soon reached in a large city, owing to the short distances between the exchanges, with the consequent lower line plant costs.

(*d*) The number of exchanges to which the subscriber has automatic access is very great, thereby requiring a large number of separate and distinct routing codes which must be used on a high percentage of outgoing calls.

(*e*) The exchange area boundaries are not so clearly defined as in less densely telephoned areas. In the medium size and smaller towns the switching equipment is divided into a number of separate exchange units primarily to obtain economy in line plant. Each exchange is normally capable of growth, and the opening of a new exchange is comparatively rare. In a city area of high telephone density, however, the number of exchanges is largely determined by the maximum practicable size of each exchange unit (normally 10 000 lines maximum). It is in fact common to

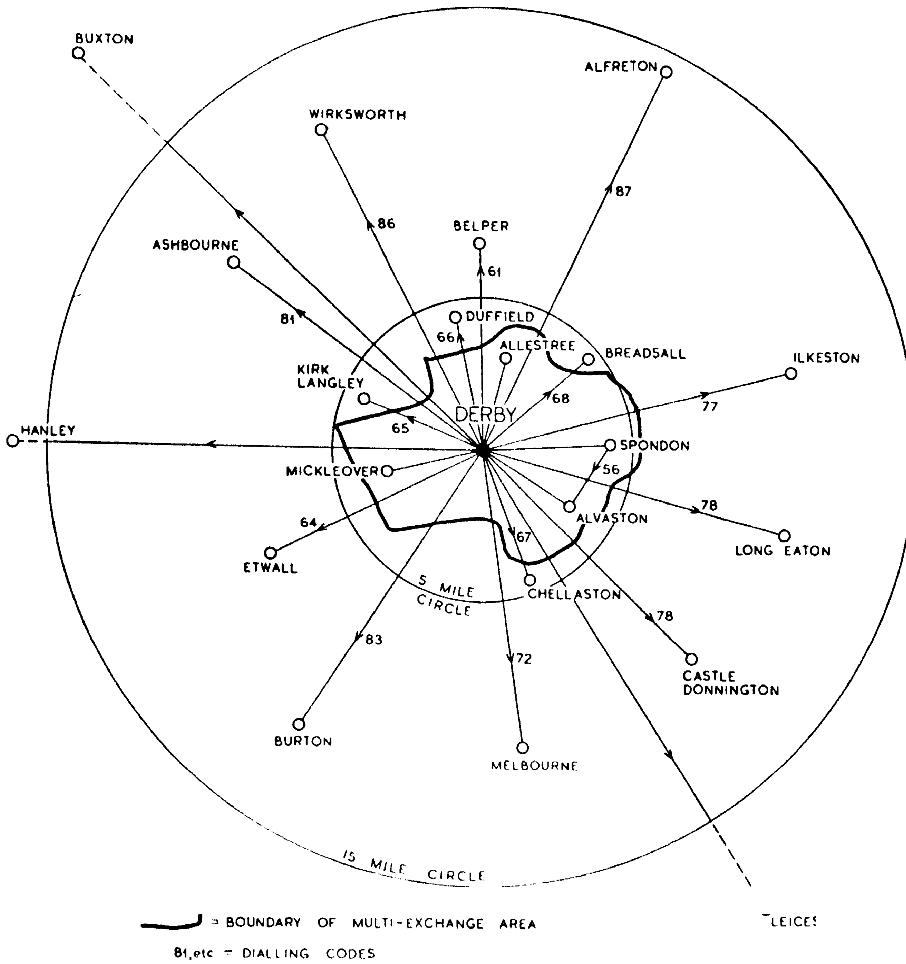


FIG. 385. JUNCTION NETWORK OF A TYPICAL NON-DIRECTOR AREA
(Note how most junction routes concentrate on the main exchange)

have two or more exchanges within half a mile of each other, and in the really densely telephoned parts of a city it is not unusual to have two or more exchange units in the same building. Telephone development in a big city usually involves the opening of new exchanges.

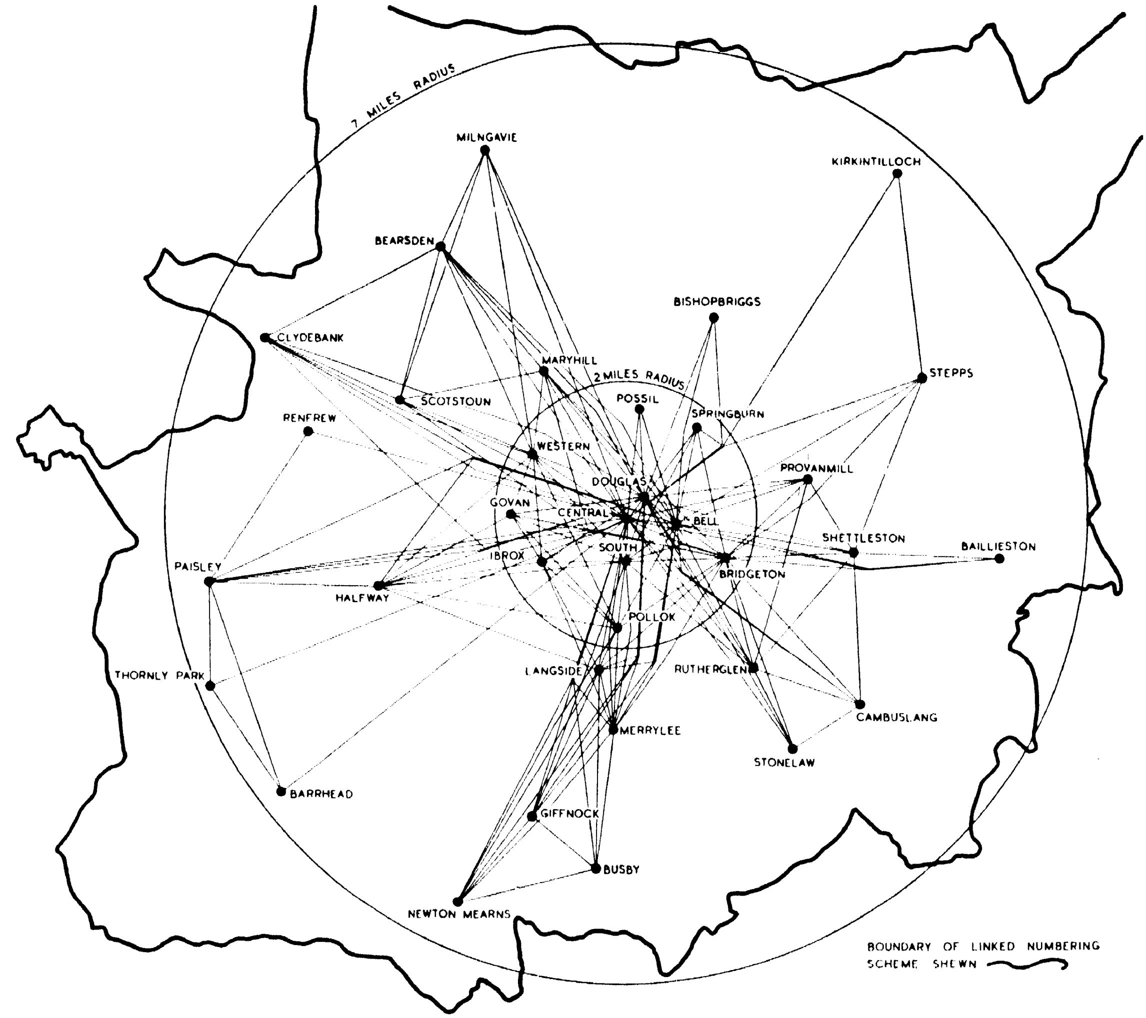


FIG. 386. JUNCTION NETWORK IN A LARGE CITY
(Note large number of direct routes between exchanges)

(*f*) The junction cable network in a large city is very complex, and as the system develops it may be desirable to re-route certain traffic groups in order to utilize the line plant in the most economical manner.

Necessity for Uniform Dialling Codes in a Large City Area. We have seen that one of the main characteristics of a heavily telephoned city area is the high percentage of traffic between a large number of exchanges which are geographically close together. We have also noted that the exchange area boundaries do not correspond with clearly defined districts. From the telephone subscriber's point of view there would be considerable confusion if the switching system necessitated the use of different dialling codes to obtain access to the same exchange from different parts of the city area. Different dialling codes can be tolerated in other circumstances where the volume of junction traffic is small and where the various exchanges are well separated geographically.

In the central part of a city area, however, the use of separate routing digits from each exchange

would very considerably complicate the directory instructions and (unless a separate directory were issued for each exchange in the area—an impossible situation) would prevent the inclusion of the routing digits in the directory numbers of the subscribers. Such a scheme would require a long dialling code list in the front of the directory, and the subscriber would have to consult this list for a large number of originated calls. Moreover, it is quite conceivable that a high percentage of calls would be mis-routed due to subscribers using the wrong routing code when making a familiar call from a telephone in a different exchange area. It can be assumed, then, that the switching system for a large city area must provide for the use of a uniform routing code which can be employed universally throughout the more densely telephoned parts of the area.

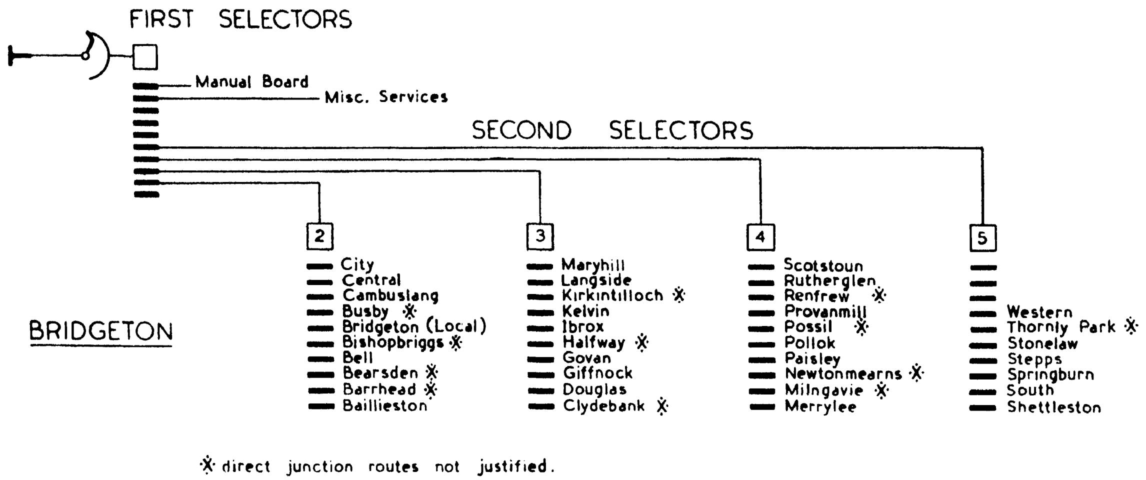


FIG. 387. A POSSIBLE TRUNKING SCHEME FOR ONE EXCHANGE IN THE GLASGOW AREA UTILIZING NON-DIRECTOR SWITCHING METHODS

The Possibilities of a Non-director Type Switching Scheme. It is interesting to examine the possibilities (and the snags) of using the non-director switching scheme in a large city. Fig. 387 shows a possible trunking scheme for one of the exchanges in the City of Glasgow. It is assumed that there is a high community of interest between all the exchanges within a 7-mile radius of the centre of the city (see Fig. 386) and that it is necessary to adopt a system of uniform dialling codes throughout this area. There are in all some 37 exchanges, and access to all these exchanges can be obtained by the provision of 4 groups of 2nd selectors trunked from 4 levels of the 1st selector banks. The remaining levels of the 1st selectors can be used for giving access to the manual board and to the miscellaneous services. If each exchange in the area requires 4 digits for the selection of a particular number on that exchange, then it is clear that the adoption of a 6-figure numbering scheme would provide 2 initial digits for the positioning of the 1st and 2nd selectors in order to route the call to the required exchange. The routing digits, being uniform throughout the area, can be incorporated in the subscriber's directory number.

The trunking scheme of Fig. 387 requires the provision of a direct route from the originating exchange to each of the exchanges within the area. This may be justified from one or two exchanges, such as Central, but is a most uneconomical arrangement for the majority of the exchanges in the area. Bridgeton exchange, for example, may well justify direct routes to the main exchanges in the centre of the city and also to some of the adjacent exchanges, but the volume of traffic to, say, Clydebank would probably justify only a very small group of junctions which could not be loaded economically.

Plant economies prohibit the provision of a large number of small groups of junction circuits, and require that such traffic should be concentrated into larger combined routes. This concentration of traffic can be obtained only by the provision of a tandem switching centre at a convenient point in the area, so that all calls to exchanges which do not justify direct routes can be passed over a common group of junctions to the tandem centre. By providing one or two ranks of selectors at the tandem exchange, it is possible to segregate the tandem traffic into the various terminal routes. In Fig. 387 there are some 12 routes which do not justify the provision of direct junctions. These

12 levels of the 2nd selectors could possibly be commoned together and routed to the central tandem switching point, but a subscriber on this exchange would now require to dial *two extra digits* to step the selectors at the tandem centre in order to obtain access to the required exchange. (Two stages of tandem selection are required since there are more than 10 exchanges in the network.)

The difficulty with such an arrangement lies in the fact that the conditions differ at each originating exchange. For example, whilst there may be no justification for direct routes from Bridgeton to, say, Bearsden and Barrhead, there may be a high volume of traffic from another exchange (e.g. Halfway) to justify direct routes to these two exchanges. Conversely, whilst there is economic justification for a direct route from Bridgeton to, say, Provanmill, there is probably insufficient traffic from Halfway to Provanmill to justify such a route. Hence, additional digits to route a call via tandem would be required on calls from some exchanges and not on calls from other exchanges. Thus, the scheme defeats the primary and initial intention that there should be a uniform dialling code from all exchanges in the area. This difficulty is not unsurmountable. It would be possible to arrange for a 4-digit routing code on all calls. The 2nd selectors at any one exchange could be made to absorb the 3rd and 4th digits if a direct route is provided from a particular exchange, and to transmit these digits to the tandem centre if no direct route is available. This would permit of tandem switching where necessary, and at the same time would give a uniform system of dialling throughout the area. An obvious disadvantage of the arrangement is that it requires the subscriber to dial additional digits which are required only on a very small percentage of the calls. In addition the selector circuits are more complex and more costly due to the inclusion of the digit absorption facilities.

Probably the greatest defect is, however, the necessity of restricting the tandem switching to two stages or, alternatively, still further increasing the number of digits to be dialled by the subscriber and to be absorbed by the group selectors on directly routed calls. In the larger cities some plant economies can be obtained by providing a main tandem switching centre and a number of sub-tandem switching centres. The principle is illustrated in Fig. 388. If there is only one main tandem exchange in the area, a call from exchange Z to exchange V requires the use of two comparatively long junction circuits. By providing a sub-tandem exchange A, however, traffic from Z to V requires the use of two much shorter junction links. The sub-tandem exchanges are linked as required with one another and to the main tandem exchange. In some cases (e.g. on a call from W to Y) the call is switched at sub-tandem B over a main route to the main tandem, and thence to the terminal exchange. Some exchanges may have direct routes to the main tandem, and to one or more of the sub-tandem exchanges in the area (e.g. exchanges X and V). This scheme of sub-tandem working not only provides some economies in the external line plant, but also avoids the very high concentration of equipment at a central switching point. The provision of sub-tandem exchanges may require extra digits for the routing of the call, and in large

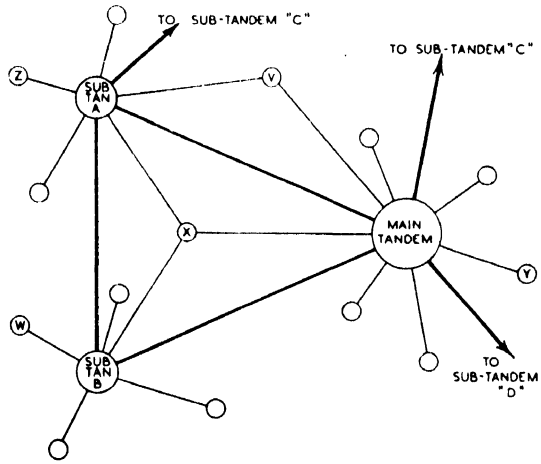


Fig. 388. Tandem and Sub-tandem Switching Centres

areas such as London the most economical routing arrangements can be obtained only by the use of up to 4 or 5 digits. It is clearly not possible to ask the subscriber to dial, say, 5 routing digits plus a further 4 digits for the numerical selection at the distant exchange. Selector circuits which would absorb, say, 3 or 4 digits on directly routed calls are also too complex to warrant their adoption in practice.

There is a further important disadvantage with the simple trunking scheme of Fig. 387. Certain exchanges can justify only a comparatively small number of direct routes, but the trunking scheme requires the allocation of a 2nd selector level for each exchange in the area, irrespective of whether or not a direct route is justified. In a small exchange in the Glasgow area, for example, only, say, 5 direct routes may be justified, the traffic on the remaining levels of the 2nd selectors being routed over a common group of junctions to tandem. One such level will theoretically suffice

for the tandem route, and hence there is a wastage of some 31 2nd selector levels. This is a most inefficient trunking scheme and one to be avoided. Moreover, it is necessary to allocate the levels on a uniform basis throughout the area in order to provide a universal dialling scheme. At one exchange it may so happen that there is a fairly even distribution of traffic over the 4 groups of 2nd selectors, but this distribution of traffic will vary widely at the different exchanges in the area. At some particular exchange, for example, there may be a very heavy traffic density on one group of 2nd selectors, whilst one of the other groups may be carrying a comparatively small volume of traffic. The converse conditions may apply at another exchange. Such inequalities of traffic materially reduce the trunking efficiency of the exchange, and necessitate the provision of more selectors than would be required if the various 2nd selector groups could be evenly loaded.

Translation. It is clear from the preceding paragraphs that with a simple non-director trunking scheme it is impossible to reconcile the two basic requirements of a large city area, i.e. the necessity for a uniform dialling code and an exchange trunking system which is both efficient and flexible. The only satisfactory solution to the problem is to provide equipment at the exchange which will, on receipt of a dialling code from the subscriber, transmit the necessary impulse trains to route the call in the most economical manner. This process is known as *translation* and is used throughout the world in every telephone system designed for use in large cities. The provision of translation facilities has the following important advantages:

(*a*) The routing code dialled by the subscriber can be uniform throughout the area—irrespective of the way in which the call is established.

(*b*) The number of digits in the routing code is a minimum, and is entirely independent of the impulse trains required to position the selectors. A 2-digit code will theoretically provide for access to 100 different exchanges, whilst a 3-digit code will suffice for a network of up to 1000 exchanges.

(*c*) Translation permits the use of an easily remembered routing code.

(*d*) The outgoing junction routes can be accommodated on the selector levels at the originating exchange in a way which will provide the most economical trunking arrangement, i.e. the busier routes can be allocated to 1st selector levels, whilst the less busy routes can be placed on the levels of 2nd or subsequent selectors.

(*e*) The number of selector groups can be reduced to the theoretical minimum necessary to provide the required number of outgoing routes.

(*f*) It is possible to route the call through any number of switching stages in order to reach the called exchange in the most economical way. Impulse distortion and the time necessary to establish the call are limiting factors in practice.

(*g*) As the system grows, it is readily possible to modify the routing arrangements without in any way altering the code dialled by the subscriber.

(*h*) The selectors are stepped by mechanically generated impulse trains sent out by the translation equipment. The frequency and ratio of these impulses can be kept within finer limits than is possible with a subscriber's dial. As a result the adoption of a translation scheme can materially improve the dialling limits of the system.

(*i*) The equipment provided for translation purposes can, with little additional expense, be made to give other facilities such as the control of metering, etc.

The trunking flexibility of a translator scheme is illustrated in Fig. 389 which shows hypothetical arrangements at two of the exchanges in the Glasgow area. These two trunking diagrams should be compared with the non-translator scheme already considered in Fig. 388. The upper part of Fig. 389 shows the arrangements at Bridgeton exchange. The heavy traffic routes are accommodated on the levels of the 1st selectors, whilst the two separate groups of 2nd selectors provide accommodation for all the remaining direct routes from this exchange. This compares very favourably with the four groups of 2nd selectors previously necessary, and it is, moreover, possible to control the traffic in each group by planning carefully the allocation of the levels. The allocation of levels can and will differ at each exchange in the area, At Scotstoun, for example (lower part of Fig. 389). all the direct routes can be provided by the 1st selectors and by one group of 2nd selectors. If a subscriber on Bridgeton exchange dials the code for Maryhill, the translator will transmit the digits 23 in order to step the 1st selector to the 2nd level, and the 2nd selector to the 3rd level where the Maryhill junctions are terminated. If a subscriber on Scotstoun exchange dials the same routing code for Maryhill, the translator at his exchange transmits the digits 11 to route the call to the Maryhill junctions, which are here accommodated on the 1st level of the 2nd selector bank.

The scheme provides complete flexibility in the allocation of levels but, as will be seen later, there is some standardization of levels in order to provide a degree of uniformity. One level at each exchange

is allocated to the tandem junction group. If there is no direct route to any particular exchange, the translation equipment steps the local selectors to reach the tandem route, and then transmits additional impulse trains to position the tandem selectors as required. It is possible to have several routes to different tandem centres, and the traffic can be routed through any particular tandem exchange as required merely by providing the correct translation.

In order to differentiate between the ordinary numerical selectors of an exchange and the switches which provide for the routing of traffic to the desired exchange, it is usual to refer to the latter as *code selectors*. The first rank of selectors are consequently known as 1st code selectors, the second rank as 2nd code selectors, and so on.

Digit Storage. The provision of translation facilities for the routing digits necessitates the adoption of an impulse storage system for the numerical portion of the called subscriber's number. As will be seen later, the translation equipment in the Post Office standard system makes provision for a maximum of 6 consecutive impulse trains to position the various code and tandem selectors, i.e. up to 6 switching points can be introduced in the chain of connexions to the required exchange. All these selectors must be positioned before the selectors at the distant exchange are ready to receive the numerical portion of the subscriber's number. The calling subscriber dials a uniform code, consisting of 3 digits, and then proceeds to dial the numerical portion of the number with an interdigital pause which may be something less than 500 msec. The correct routing of the call cannot be determined until the 3rd digit is received by the translation equipment. This equipment may then have to transmit up to 6 consecutive impulse trains to position the various selectors. Obviously this cannot be done in the short interval between the receipt of the 3rd code digit and the transmission of the first numerical digit. It is therefore necessary to provide equipment in the translation apparatus which will receive the numerical digits from the subscriber and re-transmit them in their original form after the call has been established to the required exchange. Thus, storage of the numerical portion of the number is an essential requirement in any system where provision is made for translation of the routing digits.

Alphabetical Routing Codes. The exchanges of a large city area are invariably of the 4-digit type, with a theoretical capacity of 10 000 lines. By prefixing the 4-digit number by 2 further digits, it is possible to design a numbering scheme which will provide for an area of up to 100 exchanges. This is insufficient for a very large area such as London, and a total of 7 digits is required to give separate dialling codes for the several hundreds of exchanges within the area. A subscriber in a provincial town may have to dial a 2- or 3-digit code as the prefix to a 4-digit number. In a provincial system, however, such calls represent only a very small percentage of the total

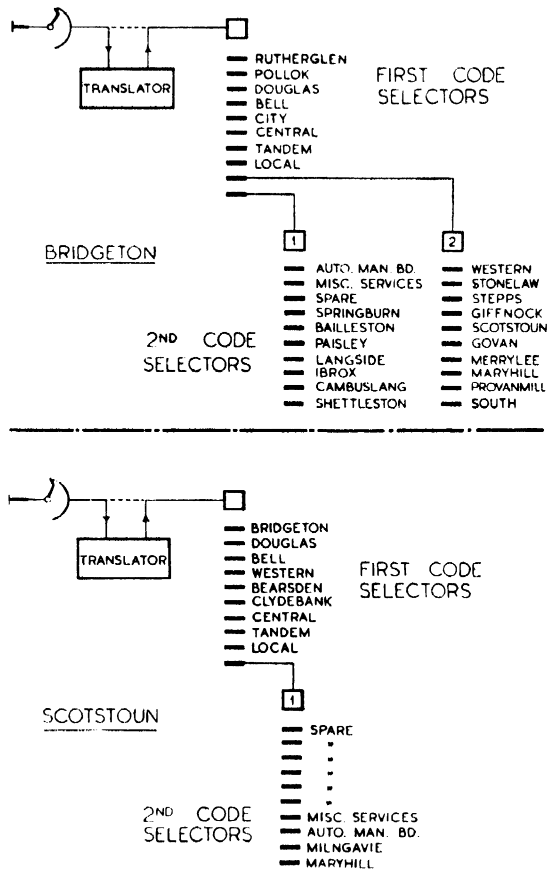


FIG. 389. IMPROVEMENTS IN TRUNKING OBTAINABLE BY THE USE OF A TRANSLATOR CIRCUIT

calls made by the subscribers. It may therefore be reasonable to expect a subscriber *occasionally* to dial 7 or even more digits, but if such calls represent a high proportion of the total calls, then consideration should be given to the possibility of simplifying the dialling procedure. Some subscribers have a little difficulty in memorizing a 7-digit number, and it is of material benefit to such subscribers if a number of more than, say, 6 digits can be split into two portions. One method is to divide the number in the directory entry. For example number 8765432 could be shown as

876—5432 or 876.5432. As an alternative, the subscriber's dial can be engraved with letters as well as figures. By this means the routing part of the subscriber's number can be shown in the directory as a letter code followed by the numerical portion of the number, e.g. if T = 8, P = 7, and M = 6, a subscriber's number which consists of the 3 routing digits 876 followed by the numerical portion 5432 can be shown in the directory as TPM5432. With this scheme it is, of course, not necessary that the whole of the routing digits should be converted to letter codes. In some telephone administrations the first 2 digits are dialled as letters, whilst the third is left as a numeral, e.g. TP65432.

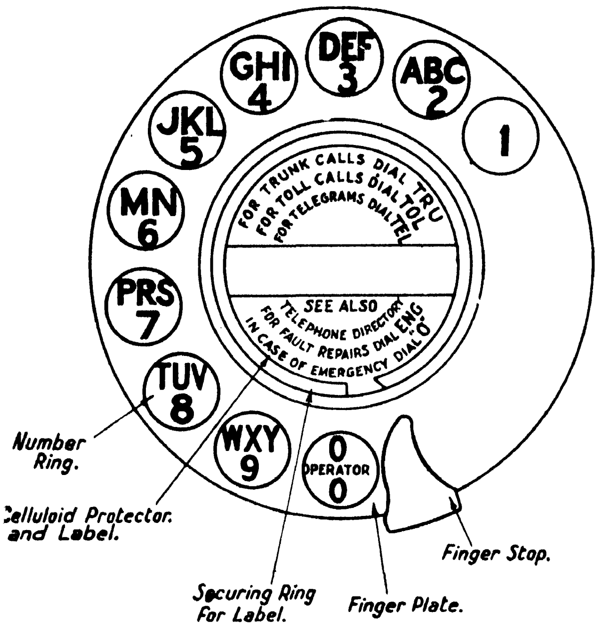


FIG. 390. FRONT VIEW OF DIAL WITH LETTERS AND NUMERALS

Fig. 390 shows the standard letter dial used in the British telephone service. There is no letter equivalent for the numeral 1, so that the letters start at the second finger hole and proceed as follows:

1	No letter equivalent
2	ABC
3	DEF
4	GHI
5	JKL
6	MN
7	PRS
8	TUV
9	WXY
0	O (Operator)

It will be noted that the letter O is placed out of sequence and is allocated to the same finger hole as the numeral 0 in order to avoid confusion. The letters Q and Z are omitted from the dial for reasons which will be seen later. To clarify the markings, the letters are enamelled in black and the figures in red.

The dialling of a large number of digits can be further simplified if means can be found of identifying the initial code letters with the name of the exchange. The translation facilities permit the use of any suitable code irrespective of the digits required to position the selectors. The only limitation is that no two codes shall be the same. In this country the 3 initial digits of the subscriber's number required for exchange routing purposes take the form of a 3-letter code formed by the 3 initial letters of the exchange name. Thus the dialling code for Enterprise 1234 is ENT1234. (From an electrical point of view this complete dialling code is equivalent to the 7 numerical digits 3681234.)

The only difficulty of utilizing the 3 initial letters of an exchange name is that it materially reduces the number of exchange codes available, and also places rather stringent restrictions upon the names given to the various exchanges in the area. It is not, for example, possible to conceive an exchange name which has the 3 initial letters XPY. Similarly it is not possible to have two exchange names with the same numerical equivalent. Thus, BRIxton and CRIcklewood each have the same numerical equivalent 274, and cannot be used together in the same network. Although a 7-digit scheme will provide a theoretical maximum of 1000 exchange codes, the number available in practice is very considerably less than this figure. (The absence of letters in finger hole No. 1 and the restriction of the last finger hole to the letter O are also limiting factors.)

Berry G. C, 55 Allen rd	**BEC**kenhm	2729
Berry G. C, 63 Chandos rd N.2	**TUD**or	5902
Berry G. E. G. 14 Court rd	Orpingtn	4217
Berry George, 57 Chingford av E.4	**SIL**vrthn	4117
Berry George, 76 Westbourne ter W.2 . . .	**PAD**dngtn	0515
Berry George & Co, 35 Rectory rd	HAYes	1295
Berry George E, 9A Holtwhites hill	**ENF**ield	4903
Berry Geo. H, 129 Riverview rd Ewell . . .	**DER**went	1649
Berry Geo. H, 38 St. Nicholas lane	Laindon	2263

FIG. 391. EXTRACT FROM LONDON TELEPHONE DIRECTORY

Fig. 391 shows a typical extract from the London Telephone Directory. Where the subscriber is required to dial the 3 initial letters of the exchange name followed by the 4-digit subscriber's number, the directory entry shows the 3 initial letters in heavy type, e.g. **TUD**or 5902. Exchanges outside

the automatic area are shown in small type (e.g. Laindon 2263). In some cases the first 3 letters of the exchange name are shown as capitals but are not in heavy type (e.g. HAYes 1295). Such entries refer to manual exchanges in the automatic area, and the subscriber is required to dial only the It is also convenient for reference to be able to describe the 3 initial code letters which prefix the subscriber's number. The first letter is commonly known as the A digit, the second letter as the B digit, and the third letter as the C digit.

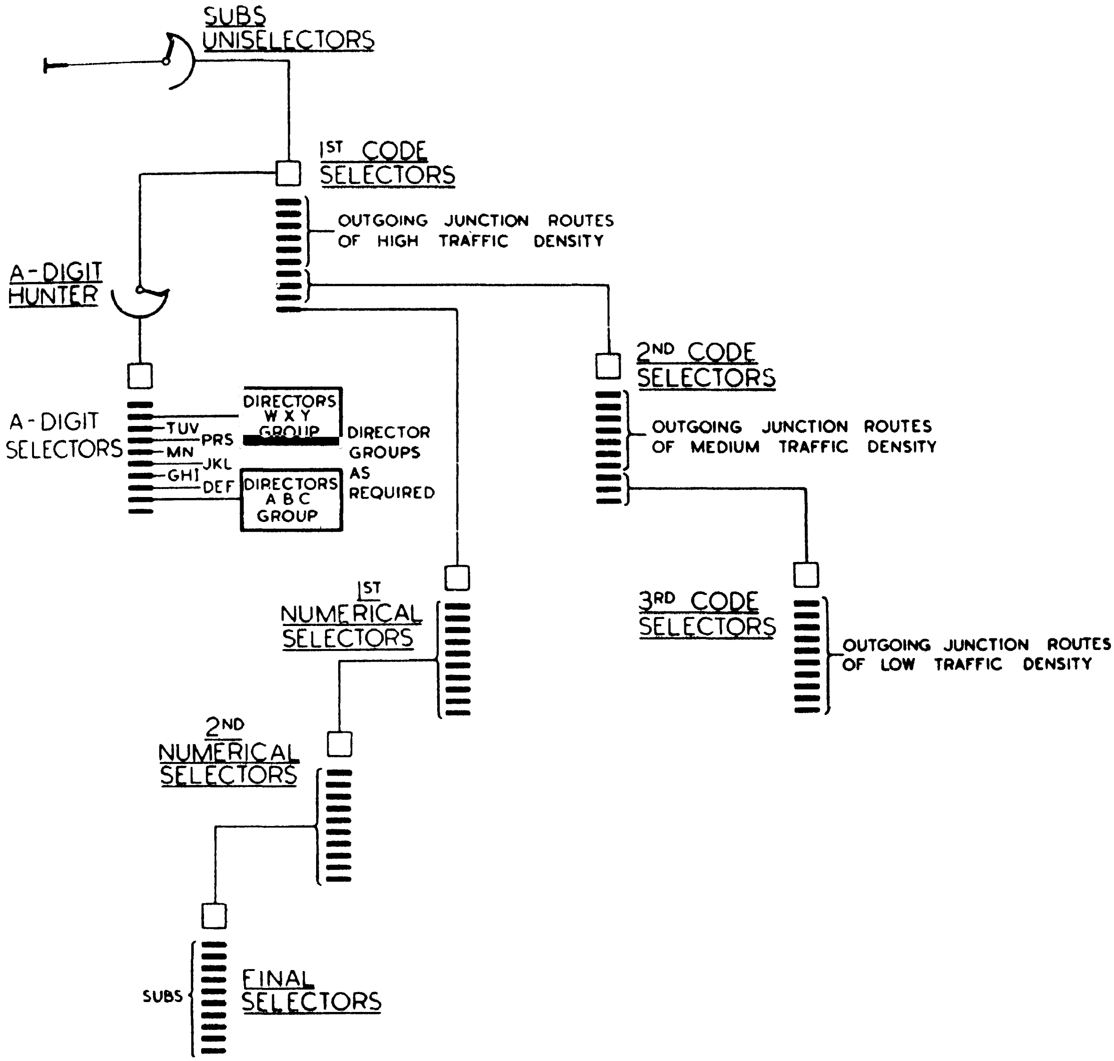


FIG. 392. BASIC TRUNKING ARRANGEMENTS OF DIRECTOR EXCHANGE

first 3 letters of the exchange name but not the numerical portion of the number. The handling of traffic to and from manual exchanges in an automatic area is dealt with in more detail in Chapter XVII.

We have seen that the first digit of a 4-figure subscriber's number is known as the thousands digit, the second as the hundreds digit, the third as the tens digit, and the last as the units digit.

The Director System. In the system developed for use in large cities in the British Isles, the piece of equipment which provides the routing code translation is known as a *director*. Hence, the system has become known as the *director system* of switching to distinguish from the *non-director system* used in the smaller provincial towns.

Fig. 392 shows the general trunking arrangements of a director exchange. The main point to

note is that the translation equipment is divided into two parts—*A-digit selectors* and *directors*. It would be possible to design a director which would receive the 3 initial digits from a subscriber's dial, determine the correct routing digits to position the selectors, and then transmit these digits to establish the call. Such a piece of equipment would require to cater for some hundreds of different dialling codes, and the cross-connexions in the equipment to provide the required translations would be extensive. This would result in a very cumbersome and complex unit which would probably be difficult to maintain. The arrangements are simplified in practice by providing (theoretically) a separate group of directors for each initial digit of the letter code. For example, there is a group of directors which deals solely with those exchange codes where the initial letter is A, B, or C (digit 2). A second group of directors deals with exchange codes which have initial letters D, E, or F, and so on. Thus, any one director is required to provide facilities for a theoretical maximum of 81 dialling codes. (The B and C digits can each have any one of 9 different values.) The correct group of directors is determined by the A-digit selector which responds to the initial letter dialled by the subscriber.

When the calling subscriber lifts his receiver, his uniselector hunts for and seizes a free 1st code selector with which is associated an *A-digit hunter*. The A-digit selectors are placed in a pool common to the whole exchange and are terminated on the banks of the A-digit hunters. When a 1st code selector is seized, the A-digit hunter automatically searches for and selects the first free A-digit selector. Dial tone is now returned to the calling party, and, on receipt of the first (A) digit, the A-digit selector steps to the appropriate level (i.e. if the letter C is dialled, the wipers step to the 2nd level). At the end of the impulse train, the wipers automatically cut into the bank and search over the level to seize the first free director in that group. The B and C digits from the subscriber's dial position a 2-motion selector (known as the "*BC* switch") in the director circuit. The destination of the call is now fully determined by the positioning of the wipers of the *BC* switch in the director circuit. The bank contacts of this selector are cross-connected as required to the banks of a sender switch, so that, at the appropriate time, the required series of impulse trains are transmitted to step the various code and tandem selectors.

The director now receives the numerical portion of the called subscriber's number, and whilst this is being recorded, the director sends out the routing digits as determined by the cross-connexions between the *BC* switch and the sender switch banks. The outgoing impulse trains are passed back through the A-digit selector and the A-digit hunter to the 1st code selector. The first impulse train steps this last selector to the required level, and subsequent impulse trains position the 2nd code, 3rd code, and possibly tandem, selectors to switch the call through to the required exchange. When the routing code has been fully transmitted, the director re-transmits the numerical portion of the number to step the selectors at the terminal exchange. If the call is local, it is routed to a 1st numerical selector and thence to a 2nd selector in the required group, and ultimately to a final selector in the home exchange. In order to minimize the number of switches at each code selector stage, it is usual to allocate the levels so that the routes of high traffic density are terminated on the banks of the 1st code selectors, whilst those routes which carry less traffic are placed on the banks of 2nd, and possibly 3rd, code selectors.

When the director has completed the transmission of the numerical portion of the called subscriber's number, the A-digit selector and the director are no longer required and are released for use on a succeeding call. The average holding time of the director and A-digit selector is of the order of 20 sec and so, by placing these items in a common pool, a comparatively small number will suffice to establish a large number of connexions.

Grouping of Directors. It has been stated in the previous section that the directors are divided into a number of groups corresponding to the levels of the A-digit selector. There are 8 possible initial digits (ABC, DEF, GHI, etc.) excluding the "0" level which is the standard code for obtaining access to the automanual exchange operator. This does not mean, however, that it is always necessary to provide 8 separate groups of directors. In some cases it is possible to common several levels of the A-digit selector bank, and to provide one common group of directors to serve these levels. If in any particular circumstances this is possible, then switching plant economies can be effected due to the higher efficiency of a large group of directors as compared with several smaller groups.

The possible groupings of A-digit selector levels are determined by the numerical equivalents of the exchange names in the network. For purposes of illustration let us assume that a certain director area consists of 30 exchanges named as in the tabulation shown on page 383.

The equivalent numerical digits corresponding to the first three letters of the exchange names are

shown in the second and third columns of the tabulation. The first digit in each case determines the level to which the A-digit selector is stepped, whilst the two final digits of the code are used to position the *BC* switch in the director. It is clear that a number of A-digit selector levels can be commoned together provided that the numerical

Exchange Name	Equivalent Numerical Digits 1st	Equivalent Numerical Digits 2nd and 3rd	Director Groupings
ABBey	2	22	Director Group 1—Serving A-digit Levels 2 and 3
ACOrn	2	20	
ARChway	2	72	
BARnet	2	27*	
BATtersea	2	28	
CLIssold	2	57	
CROydon	2	70	
EALing	3	25†	
ENField	3	63	
ENTerprise	3	68	
FELtham	3	35	
GLAdstone	4	52	Director Group 2—Serving A-digit Levels 4 and 7
HARrow	4	27*	
HENdon	4	36	
HOUnslow	4	08	
KINgston	5	46	Director Group 3—Serving A-digit Levels 5, 6, and 8
LARkswood	5	27*	
LIVingstone	5	48	
MAIda Vale	6	24	
MALden	6	25†	
MAYfair	6	29	
PERivale	7	37‡	
POLlards	7	05	
PUTney	7	88	
RIPpleway	7	47	
SLOane	7	50	
TERminus	8	37‡	
TUDor	8	83	
UPLands	8	75	
VICtoria	8	42	

equivalents of the second and third digits are all different. There are seven exchange codes (**ABB**ey to **CRO**ydon) routed from the 2nd level of the A-digit selectors, and a further four exchange codes (**EAL**ing to **FEL**tham) routed from the 3rd level of the A-digit selectors. The numerical equivalents of the two final digits of all these ten exchanges are different, i.e. the *BC* switch in the director is stepped to a different position for each exchange, and hence it is possible to combine levels 2 and 3 of the A-digit selector banks and to serve these levels by one larger group of directors. It is not possible to extend this commoning to include the 4th level due to the fact that the second and third digits (27) for **HAR**row clash with the two final digits of the code for **BAR**net. Similarly, it is not possible to combine levels 4 and 5 due to the clash between **HAR**row and **LAR**kswood. In the same way levels 7 and 8 cannot be combined due to the identical numerical equivalents of the last two digits (37) of the codes for **PER**ivale and **TER**minus. An analysis of the numerical equivalents of levels 4 to 8 shows that it is possible to combine level 4 with level 7 and to serve both these levels from Director Group No. 2. Similarly, it is possible to combine levels 5, 6, and 8 without a clash of the codes. These three levels are therefore served by a common group of directors (No. 3). Thus, in the illustration given, three comparatively large director groups can be made to serve all the exchange codes in the network. Outside London it is usually possible to arrange the directors into four or less groups.

Special arrangements are required for "0" level calls. Such calls are an exception to the general rule in that provision must be made to route the call to the manual board on receipt of a single digit. This digit is absorbed by the A-digit selector so that, when the latter seizes a director, the required routing code is automatically pulsed out without waiting for further impulse trains from the subscriber. This unusual facility could be provided by a group of special directors connected to the "0" level of the A-digit selectors, but, owing to the comparatively small amount of traffic, this group would be very small and the traffic capacity per director would be poor. The arrangements adopted in practice consist of combining the "0" level of the A-digit selector with some other convenient level and arranging for a special signal to be sent to the group of directors to indicate when a manual board routing is required. This facility is dealt with in some detail later.

Allocation of Code Selector Levels. The translation features of the director enable the 1st, 2nd, and 3rd code selector levels to be allocated to the various outgoing junction groups in any desired order. The total quantity of switching equipment required to give a standard grade of service can, however, vary between wide limits depending upon the care which is taken in the allocation of the code selector levels. If, for example, all the routes of heavy traffic density were placed on, say, the levels of 3rd code selectors, then not only must the group of 3rd code selectors be sufficiently large to carry the heavy volume of traffic, but,

since this traffic must be routed through 1st and 2nd code selectors, there is a correspondingly large number of selectors in the earlier stages. Much of this switching equipment could be avoided

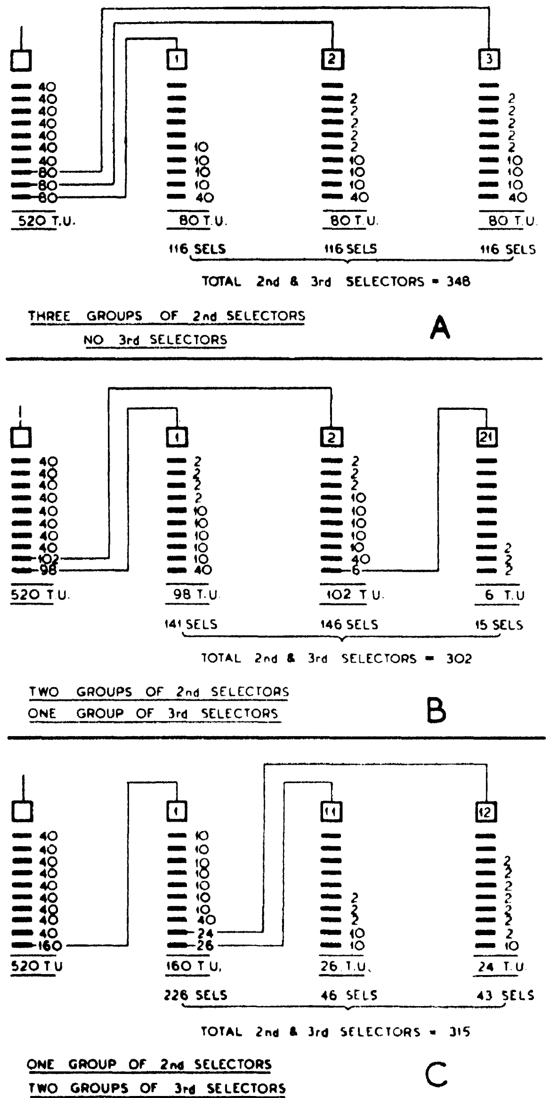


Fig. 393. Alternative Method of Allocating 30 Junction Groups to Code Selector Levels

if the routes of high traffic density were allocated to the 1st code selector levels, leaving the 2nd and 3rd code selector levels available for the routes which carry lighter traffic.

The general principle, therefore, in the allocation of code selector levels is to concentrate the routes of highest traffic density on the 1st code selector levels as far as is possible. The routes of medium density are located on the 2nd code selector levels, whilst the small junction groups which carry light traffic are allocated to the 3rd code selector levels.

In any director exchange the number of code selector levels required is determined by the number of outgoing junction routes from the exchange, due allowance being made for additional routes to meet growth. In any particular case it is possible to provide the required number of levels in several alternative ways. The code selectors of a director exchange with, say, 50 outgoing routes could, for example, be arranged in the following alternative ways:

(*a*) Five groups of 2nd code selectors, each group being accessible from a level of 1st code selectors.

(*b*) Four groups of 2nd code selectors with one group of 3rd code selectors accessible from one level of a particular group of 2nd code selectors.

(*c*) Three groups of 2nd code selectors, with two groups of 3rd code selectors.

(*d*) Two groups of 2nd code selectors, with three groups of 3rd code selectors.

(*e*) One group of 2nd code selectors, four levels of which give access to four groups of 3rd code selectors.

Each of the above combinations provides for a total of 55 levels which are available for outgoing routes. If the flow of traffic on each of the levels is substantially the same, then the best arrangement is the one which needs the minimum number of code selector stages, i.e. alternative (*a*) is undoubtedly the best from a switching economy point of view. In actual practice, however, the traffic varies between very wide limits on the various routes. The B.H. traffic to a nearby exchange or to the exchange serving the business quarter of the city may be as much as 50 T.U. or more, whilst the traffic on routes to more distant exchanges may be as low as 2 or 3 T.U. In these circumstances the best arrangement of code selectors may not be obvious at a first examination, and it becomes necessary to make detailed calculations to determine the most economical switching arrangement.

Fig. 393 shows a very simple example. It is assumed that a total of 30 outgoing routes is required from the exchange. (This figure includes the route to the automanual board, miscellaneous services, etc.) It is possible to provide the required facilities in three alternative ways. The first (scheme *A*) envisages three 2nd code selector groups with no 3rd code selectors. The second arrangement (scheme *B*) provides for two 2nd code selector groups with a single 3rd code selector group. The third alternative (scheme *C*) is to

provide a single group of 2nd code selectors with two 3rd code selector groups accessible from levels of the 2nd code selectors. It is assumed for purposes of illustration, that there are 10 outgoing routes each with a traffic of 40 T.U., 10 routes each with 10 T.U., and 10 routes each with 2 T.U. per route.

The routes have been allocated in accordance with the general principle that the routes of higher traffic density are concentrated as far as possible on the earlier code selection stages. It will also be noted that in any particular group of selectors the heavier routes are allocated to the lower levels. This is normal practice and tends to minimize the time necessary to set up a large percentage of the calls and also to reduce the amount of wear on the selector mechanisms.

The number of switches of each group has been calculated for each of the three alternative arrangements. (It should be noted in this connexion that the traffic between the 1st and 2nd code selectors is treated as "smoothed" traffic, whereas the traffic between the 2nd and 3rd code selectors is regarded as pure chance—see Chapter II.) A total of 348 2nd code selectors is required for scheme *A*, whilst the total number of 2nd and 3rd code selectors under scheme *B* is 302. Scheme *C* requires the provision of 315 selectors (excluding 1st code selectors which are the same for all three schemes). It is clear that scheme *B*—with one group of 3rd code selectors—is the most economical arrangement. There is a saving with this arrangement of some 15 per cent over scheme *A*, which might at first sight appear to be the best solution. Savings of as much as 25 per cent in the total number of 2nd and 3rd code selectors can be obtained by a careful examination of the conditions in any particular exchange. It is, of course, not possible to generalize since the conditions vary so much between exchanges, but an examination of a large number of typical cases has shown that the following arrangements of code selectors represent the most economical schemes under average conditions.

No. of Outgoing Routes	No. of 2nd Code Groups	No. of 3rd Code Groups
Up to 15	1	—
16–23	2	—
24–31	2	1
32–40	3	1
41–49	3	2
50–58	4	2
59–67	4	3
68–76	4	4
77–84	5	4
85–93	5	5

Each individual case must be worked out separately—the figures given above are merely a rough guide.

Control of Metering. The translation facility provided by the director makes it possible to adopt a simple system of fee determination by grouping the exchanges on the code selector levels in accordance with their respective charge fees. It is, for example, readily possible to arrange for all exchanges in the 1-unit fee belt to be accessible (via 2nd and possibly 3rd code selectors) from, say, level 2 of the 1st code selectors. Similarly, exchanges within the 2-unit fee belt can all be connected via level 3 of the 1st code selectors, whilst levels 4 and 5 can be reserved for giving access to the 3- and 4-unit fee exchanges respectively. By the adoption of this scheme it is possible to provide a simple *level control of metering* in the 1st code selector circuit.

The metering requirements must, of course, be taken into consideration when determining the best groupings of code selectors in any particular exchange. In some cases it may not be possible to arrange for control of metering at the 1st code selector level without the adoption of a trunking scheme which is uneconomical. In these circumstances both requirements can be met by providing 2nd code selector control of metering, i.e. the appropriate fee is determined by the level to which the 2nd code selector is stepped. Unfortunately this requires an additional wire between the 1st and 2nd code selectors, and, in order to avoid the provision of special 1st code selectors with an additional wiper and bank (which would be required only on one or two levels), it is usual to obtain the additional wire by sacrificing 10 of the 20 outlets.

Main Switching Circuits. The main switching train of a director exchange is made up of the following units:

Subscriber's Uniselector Circuit. This circuit follows the same general lines as the uniselector circuit used in a non-director exchange, except that provision is made for fourth-wire metering from the 1st code selector.

1st Code Selector. This selector is of special design to provide for the repetition of the impulses from the subscriber's dial, first to the A-digit selector and then to the director. The selector is stepped by the initial impulse train transmitted by the director, and provides a pulsing-out circuit from the director through the A-digit selector and 1st code selector for the stepping of subsequent switches. The calling subscriber's transmission bridge is in the 1st code selector, and metering is applied (over a fourth wire) to the calling

subscriber's uniselector circuit on receipt of a line reversal condition from a final selector.

A-digit Hunter. This is a 25-point uniselector with the banks graded to the A-digit selectors. The relays required to control the drive and switching of the A-digit hunter are located in the 1st code selector.

A-digit Selector. This is essentially a 100-outlet group selector, but the circuit arrangements are somewhat different from the group selectors previously described. Provision is made for the stepping of the A-digit selector by earth pulses over a *PU*-wire from the 1st code selector, and for switching this pulse wire forward when a free director is found. Provision is also made for the forcible release of the A-digit selector should it be held for a prolonged period.

Director. The prime purpose of the director is to transmit the appropriate routing codes on receipt of the second and third digits from the subscriber's dial. This in turn necessitates the storage and re-transmission of the numerical digits.

2nd and 3rd Code Selectors. These selectors are identical with the 200-outlet group selector illustrated in Fig. 355.

1st and 2nd Numerical Selectors. These are also standard 200-outlet group selectors of the type illustrated in Fig. 355.

Final Selectors. The final selectors used in a director exchange are similar to those of a non-director exchange (see Chapter XI) except for the omission of metering. Generally speaking, there is a higher percentage of P.B.X. final selectors than in a non-director exchange. This is due to the greater incidence of P.B.X.s in a large city area.

A director exchange provides for the forward holding of the selector train from the 1st code selector. It is therefore unnecessary to provide relay sets on the outgoing junction routes, except where it is necessary to change from loop to some other form of signalling conditions (e.g. on routes to certain manual exchanges).

All incoming routes from other automatic exchanges in the area are terminated on 1st numerical selectors which are connected to the same common grading as the local 1st selectors. Backward holding from the final selector is provided on such incoming calls.

Communication between manual exchanges and director exchanges is considered later in Chapter XVII.

Subscriber's Uniselector Circuit. Fig. 394 shows a subscriber's uniselector circuit designed for use in a director exchange. This circuit differs from the one illustrated in Fig. 353 in that metering is effected by the application of a negative battery over a fourth wire between the subscriber's line circuit and the 1st code selector circuit. In other respects the circuit is identical with the line circuit already described for use with positive battery metering. False operation of the meter is, to some extent, guarded by the insertion of the *K*4 contact, which prevents operation of the meter to an accidental battery potential on the *M* wiper when the circuit is idle. Since metering is effected over an entirely separate wire, there is no need for a rectifier as in the circuit considered earlier.

1st Code Selector. Fig. 395 gives the complete circuit of a typical 1st code selector. The selector is seized by a calling subscriber via a linefinder or subscriber's uniselector circuit. The A-digit hunter

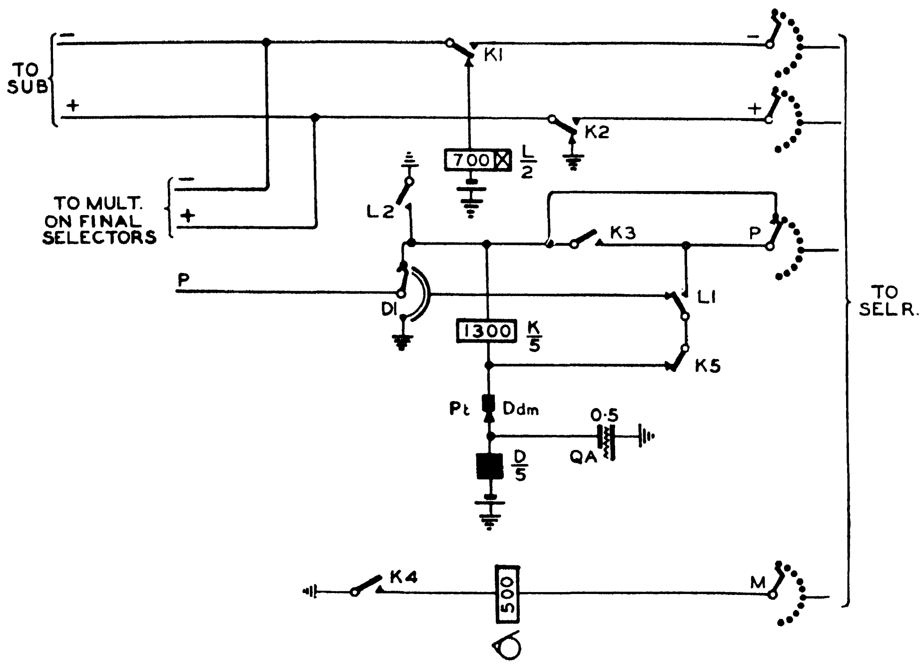


Fig. 394. Subscriber's Uniselector Circuit

associated with the 1st code selector searches for and switches to a free A-digit selector from which dial tone is returned to the calling subscriber. The selector now repeats the dial impulses first to the A-digit selector and then to the director. At the termination of the incoming routing digits, the selector is stepped vertically in response to the first train of impulses from the director. After reaching the required level, the 1st code selector automatically hunts for a free outlet to the next code selector and switches through the pulsing-out circuit of the director to enable further routing digits to be transmitted. If all outlets are engaged, the selector steps to the 11th rotary position and busy tone is returned to the calling subscriber.

On completion of pulsing out by the director the A-digit selector and the director are both released and the calling subscriber is switched through for conversation. The A-digit hunter associated with the 1st code selector now returns to its home position. On completion of an effective call, appropriate single or multi-fee metering conditions are applied to the calling subscriber's meter over a separate (*M*) wire.

A supervisory lamp is provided for "called subscriber held" or "forced release" conditions. Forced release of the A-digit selector and director is provided under permanent loop conditions or if dialling is premature or is abnormally delayed. Similar forced release conditions are applied if a spare code is dialled. A release alarm is provided should the selector carriage fail to restore or if the A-digit selector fails to step.

Seizure. The extension of the calling subscriber's loop to the 1st code selector operates relay *L*, which at ***L*1** operates the relief relay *LR*. ***LR*1** in turn operates relay *B*, whilst ***LR*2** operates relay *A* over the loop formed by the *D* and *I* relays. ***LR*3** extends a 120 Ω earth in parallel with the 500 Ω earth to relay *K* in readiness for switching when a free A-digit selector is found. ***LR*4** returns the usual earth on the *P*-wire to hold the subscriber's line circuit.

Relay *A* in operating completes a circuit at ***A*1** for the 1000 Ω pre-operate winding of relay *C*, whilst ***B*2** operates the relief relay *BB*. Contact ***C*6** now initiates a drive circuit for the A-digit hunter, and the latter drives under the action of its own interrupter contacts to the release alarm earth. When a free A-digit selector is found, a 150 Ω battery on the *P*-wire operates relay *K* to the earth at ***LR*3** and ***K*3**. ***K*1** cuts the A-digit hunter drive circuit, whilst ***K*2** operates the relief relay *KR*. The operation of ***K*3** reverses the current in the 200 Ω coil of relay *K*. This circuit arrangement enables relay *K* to release if two A-digit hunters attempt to switch to the same A-digit selector at the same time. (This has been fully discussed in Chapter VII.) Dial tone is now returned from the A-digit selector via the *FR*-lead and capacitor *QD* to the tone coil of impedance *I*.

Vertical Stepping. Relay *L* responds to the subscriber's dialled impulses, and *L*1 repeats the impulses to the A-digit selector and director over the *PU*-wire. Subsequent to the operation of ***KR***, the *A* relay of the 1st code selector is held from a loop on the positive and negative wires in the A-digit selector and finally in the director. In due course, the first train of impulses from the director pulses relay *A* which at *A*1 repeats the impulses to the vertical magnet via the 3 Ω coil of relay *C*.

The off-normal springs operate when the 1st code selector steps from normal and at **N1** energize relays *HA* and *HB* in readiness for testing. **N4** now disconnects the 200 Ω coil of relay *K* to increase the effective holding flux. Relay *C* releases at the end of the vertical impulse train and at *C*1 disconnects the vertical magnet circuit. *C*2 completes the circuit for the rotary magnet and at the same time disconnects the initial operate circuit of relays *HA* and *HB*. *C*5 disconnects the battery at *YA* to prevent unnecessary current drain.

Rotary Hunting. On the release of *C*2 the rotary magnet is energized from the earth at ***BB*5** via *M*6, *DB*5, ***HB*5**, ***HA*5**, *R*1, and **N1**. Towards the end of the rotary step, the rotary interrupter springs break and the rotary armature restores. *R* is again energized on the reclosure of *R*1, and rotary stepping continues until the drive circuit is broken at either *HA*5 or *HB*5. During rotary hunting, the switching relays *HA* and *HB* are held operated from the earth conditions on the *P*1 and *P*2 banks, and, when the wipers are passing from one contact to the next, *HA* and *HB* are held over their centre coil from the earth via ***BB*1** and *R*1.

If both outlets on the same rotary step are disengaged, both *HA* and *HB* release. *HB*1, *HB*2, and *HB*4 disconnect the —, +, and *P* wipers of outlet No. 2, whilst *HB*3 extends earth on the *P*1 wiper to guard the outlet seized. *HB*5 disconnects the rotary magnet circuit and re-operates *HA*. *HB*7 energizes *BA*. *BA*, in operating, extends the pulsing-out loop from the director at ***BA*2** and ***BA*4** to the — and + wires of the outlet seized, whilst ***BA*3** disconnects the 400 Ω coil of relay *HB*.

If the *P*1 outlet is free but the *P*2 outlet is engaged, relay *HB* releases due to the free condition encountered on the *P*1 wiper, whilst relay *HA* remains held over the 1500 Ω winding. The

release of *HB* operates *BA* as previously described, and the pulsing-out loop from the director is extended to the first outlet via **BA2**, **BA4**, **HA1**, and *S***2** connects busy tone via *C*3 to the tone coil of *I*. *S***1** disconnects the 400 Ω coil of relay *HB* to prevent the relay being affected by the

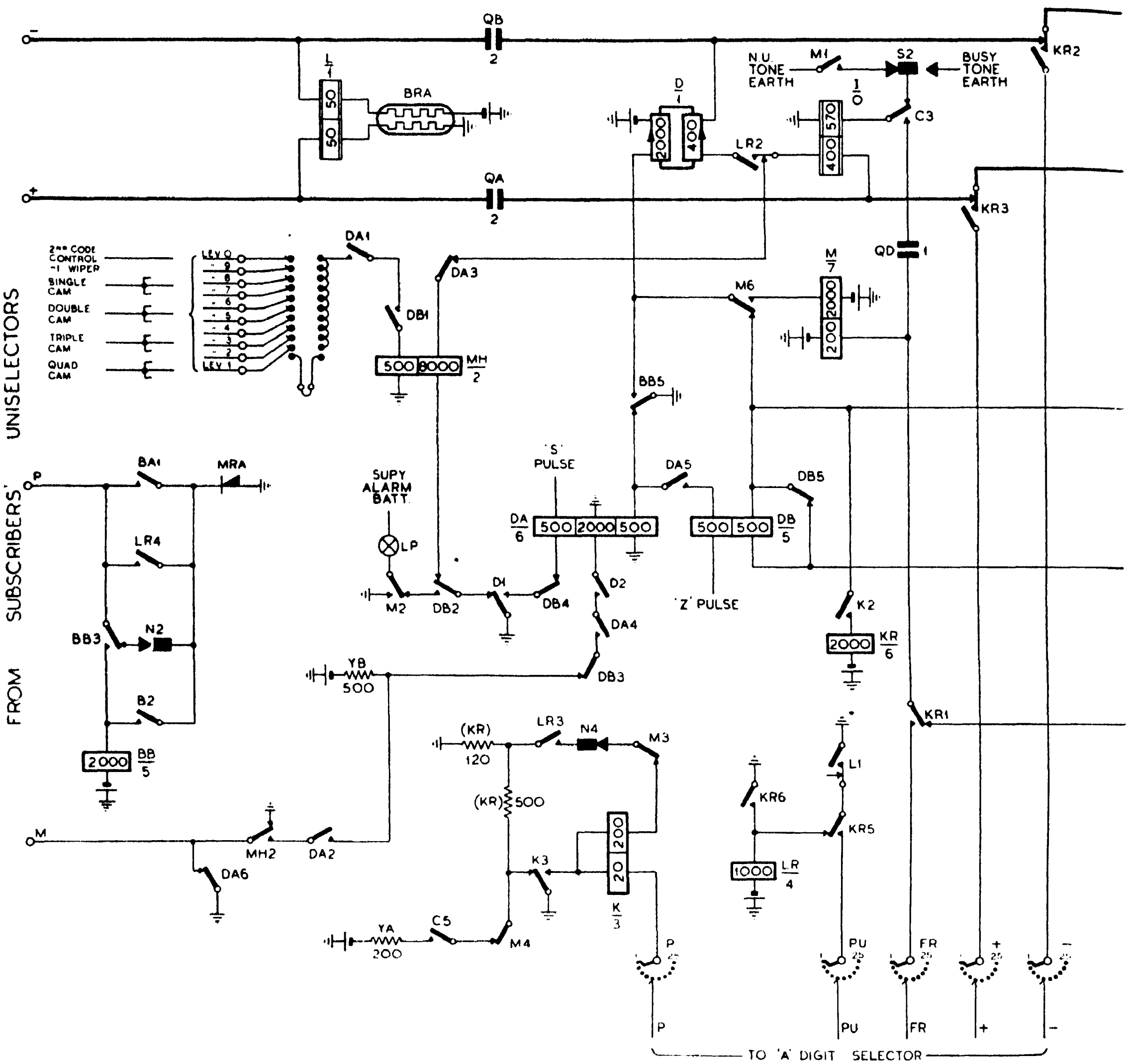


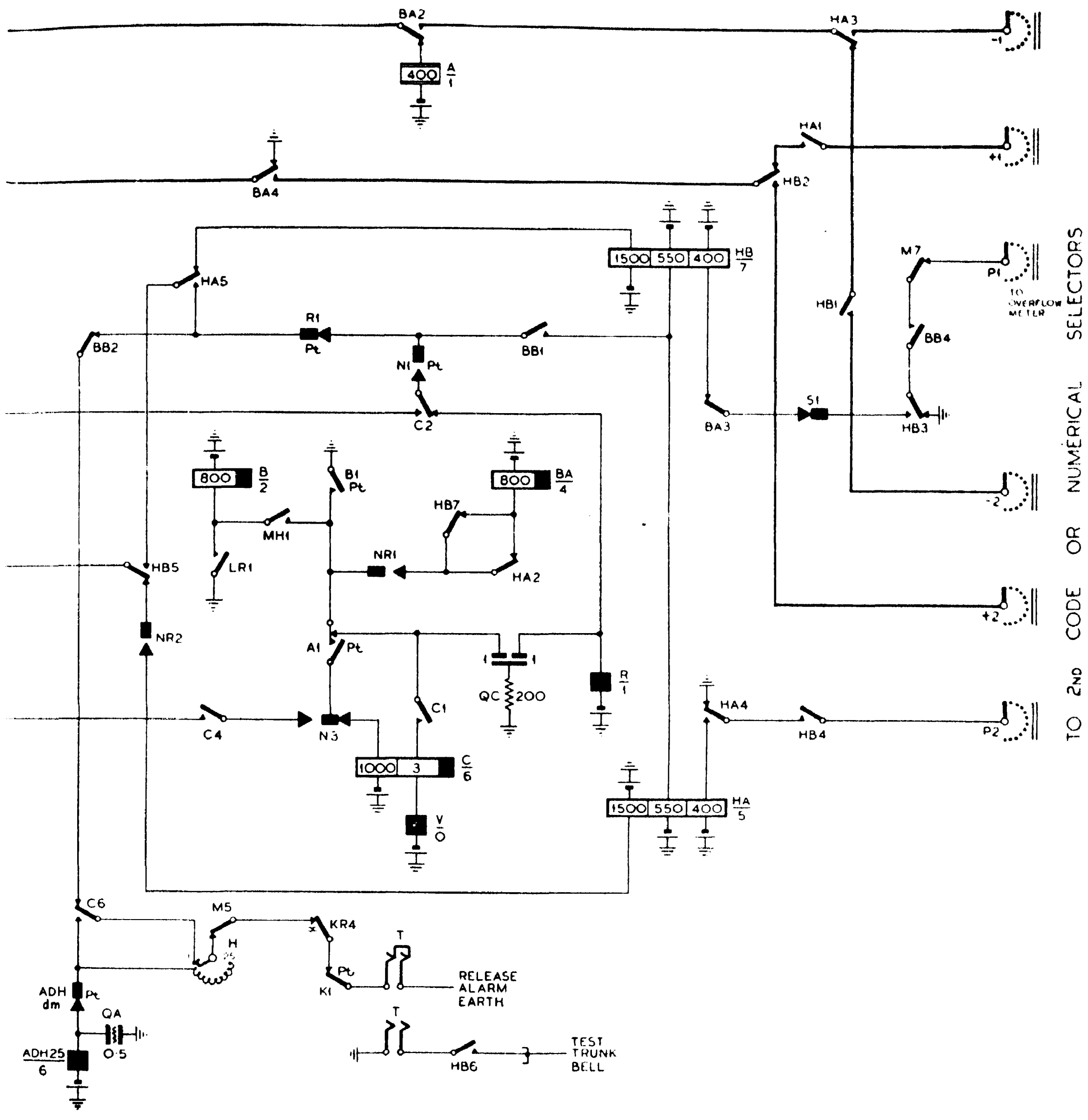
Fig. 395. 1st Code

and **HA3**. If, on the other hand, the *P*1 outlet is engaged whilst the *P*2 outlet is free, relay *HA* releases but relay *HB* remains held. The pulsing-out loop is now extended to the second choice outlet via **HB1** and **HB2**.

If all outlets are engaged, relays *HA* and *HB* both release when the switch is stepped to the 11th rotary position. The *S* springs now operate overflow meter circuit. *HB*, in releasing, extends earth on the *P*1 wiper from *HB*3 to operate the overflow traffic meter. *HB*5 disconnects the rotary magnet circuit and re-operates relay *HA* over the 1500 Ω winding to the earth at **BB5**. *HB*7 also operates relay *BA*.

Release of Director. When the director has completed the pulsing out, the A-digit selector

and the director release. The disconnexion of the P-wire in the director allows relay K in the 1st code selector to release, and at $K1$ a homing hunter and, when the latter restores to normal, the release alarm earth is extended via $C6$ in readiness for the ultimate release of the 1st code selector.



Selector Circuit

circuit is prepared for the A-digit hunter. $K3$ removes the guarding earth from the P wiper of the A-digit hunter, whilst $K2$ releases relay KR. KR, in releasing, disconnects the FR-lead at $KR1$, whilst $KR2$ and $KR3$ break the director pulsing-out loop and extend the D and I relay loop to hold and control the connexion established. $KR4$ completes the homing circuit for the A-digit

Metering. When the called subscriber replies, relay D operates to the reversed line current and at **$D1$** disconnects the manual hold circuit. The operation of **$D1$** also allows relay DA to operate to the next "S" pulse. When the pulse is received, DA operates and at **$DA4$** locks on its 2000 Ω winding. When the subsequent Z pulse is received relay DB operates via **$DA5$** and the 500 Ω coil

of relay *DA*. ***DB*1** in conjunction with ***DA*1** extends the 500 Ω coil of relay *MH* to the vertical marking bank of the selector. ***DB*3** breaks the initial holding circuit of relay *DA* which is now held to the *Z* pulse in series with *DB*. ***DB*5** removes the short circuit from the second coil of *DB* and this relay now holds (independent of the *Z* pulse) in series with the 1500 Ω coil of either *HA* or *HB*. The circuit is now prepared for the receipt of meter pulses which are applied to the 500 Ω coil of relay *MH* from the vertical marking bank. On each operation of *MH*, ***MH*2** extends metering battery to the *M*-wire. At the end of metering, relay *DA* releases when the *Z* pulse is withdrawn, and at *DA*1 disconnects relay *MH* from the vertical marking bank. *DA*2 and *DA*6 disconnect the metering battery and apply a guarding earth to the *M*-wire, whilst *DA*5 prevents any further operation of *DA* to *Z* pulses.

Manual Hold. On calls routed to a manual operator, metering is not required but manual hold facilities are normally provided. Should the calling subscriber replace his receiver before the answering plug is withdrawn from the jack, relays *L* and *LR* release and *LR*2 applies the 8000 Ω coil of relay *MH* to the positive line. *MH* now operates to a negative battery returned from the manual board and at ***MH*1** holds relay *B* to the earth at ***B*1**. *B* in turn holds *BB* and a holding earth is maintained on the *P*-wire for so long as the operator leaves her plug in the jack.

Called Subscriber Held. Should the calling subscriber fail to replace his receiver after the called subscriber has cleared, a supervisory alarm is provided to prevent the prolonged holding of the called subscriber's line. Under these conditions relay *D* releases when the called subscriber replaces his receiver and at *D*1 extends earth via ***DB*2** and *M*2 to the selector supervisory lamp.

Forced Release. It has already been explained that it is not permissible to allow A-digit selectors or directors to be held unnecessarily by the calling subscriber. The forced release feature is arranged so that, if an A-digit selector or a director is seized but impulsing is not completed within a period of from 30 to 60 sec, an earth is returned on the *FR*-wire to the 1st code selector. The forced release condition is also returned by the director if a spare code is dialled.

Relay *M* operates to this earth and locks via ***M*6** to the local earth at ***BB*5**. ***M*6** also disconnects the holding circuit for relays *KR*, *HA*, and *HB*. *KR*5 releases the A-digit selector, and the removal of the battery from the *P*-wire during the restoration of the switch allows relay *K* to release (contact ***M*3** preventing the re-operation of *K* when the A-digit selector reaches normal.) ***M*2** lights the 1st code selector supervisory lamp to give a visual indication of the forced release condition.

The *A* relay of the selector is now held by the loop formed by ***LR*2** which is in turn under the control of the line relay *L*. If the subscriber attempts to dial, the 1st code selector is stepped vertically, and, at the end of the impulse train, the release of *C*3 applies N.U. tone to the line. (It will be noted that the rotary drive circuit is disconnected at *M*6, *HB*5, and *HA*5 so that the wipers cannot cut into the bank.) This condition persists until relays *L*, *LR*, *B*, etc., release when the call is abandoned. Relay *M* is the last relay to release and contact *M*5 ensures that the release circuits of the A-digit hunter and 1st code selector are not completed until all relays are normal.

If the forced release condition is applied after the 1st code selector has been stepped from normal (e.g. if the subscriber fails to dial the later numerical digits) relay *M* operates as before. *C*3 is normal under these conditions and N.U. tone is returned immediately to the caller.

Should the calling subscriber commence dialling prior to the receipt of dialling tone (i.e. before a free A-digit selector has been found), *KR*5 is normal and relay *LR* responds to the impulses repeated at *L*1. ***LR*1** in turn pulses relay *B* which holds. *LR*2 similarly repeats the impulses via the windings of *D* and *I* to the *A* relay. Relay *A* responds to the impulses repeated at *LR*2 and *A*1 steps the selector vertical magnet. As the switch moves off-normal, the *N* springs operate and ***N*3** extends earth from ***B*1** via ***A*1**, ***N*3**, ***C*4**, and *KR*1 to operate relay *M*. Relay *M*, in operating, locks to its 2000 Ω coil and extends N.U. tone to the calling subscriber as previously described.

Release. Under normal conditions the replacement of the calling subscriber's receiver releases relay *L*, and *L*1 in turn releases *LR*. *LR*1 now releases relay *B*, whilst *LR*2 breaks the loop which is holding the distant selectors. *B*1 releases *BA* which, at *BA*1, breaks the circuit for relay *BB*. *BB*2 completes the rotary magnet circuit to restore the selector to normal, whilst *BB*3 extends earth via ***N*2** to the *P*-wire in order to guard the circuit whilst the selector is restoring to normal. *BB*5 disconnects the switching relay (*HA* or *HB*) to remove the earth from the *P*-wire which is holding other local switches (under forced release conditions *BB*5 also releases relay *M*). It will be noted that the earth for the A-digit hunter and rotary magnet circuits is applied through an alarm circuit which, in the event of either magnet being

energized for a period in excess of 30 sec, brings in a release alarm condition.

A-Digit Selector. The complete circuit of an A-digit selector is given in Fig. 396. The circuit is essentially similar to that of a 100-outlet group selector with additional facilities. The selector is seized over the *P*-wire from the 1st code selector both the director and the A-digit selector. If the A-digit selector is seized by a subscriber but is not stepped within a period of from 30 to 60 sec, forced release conditions are applied to free the selector.

Seizure. Relay *A* (Fig. 396) is operated on its 240 Ω coil by the earth extended on the *P*-wire

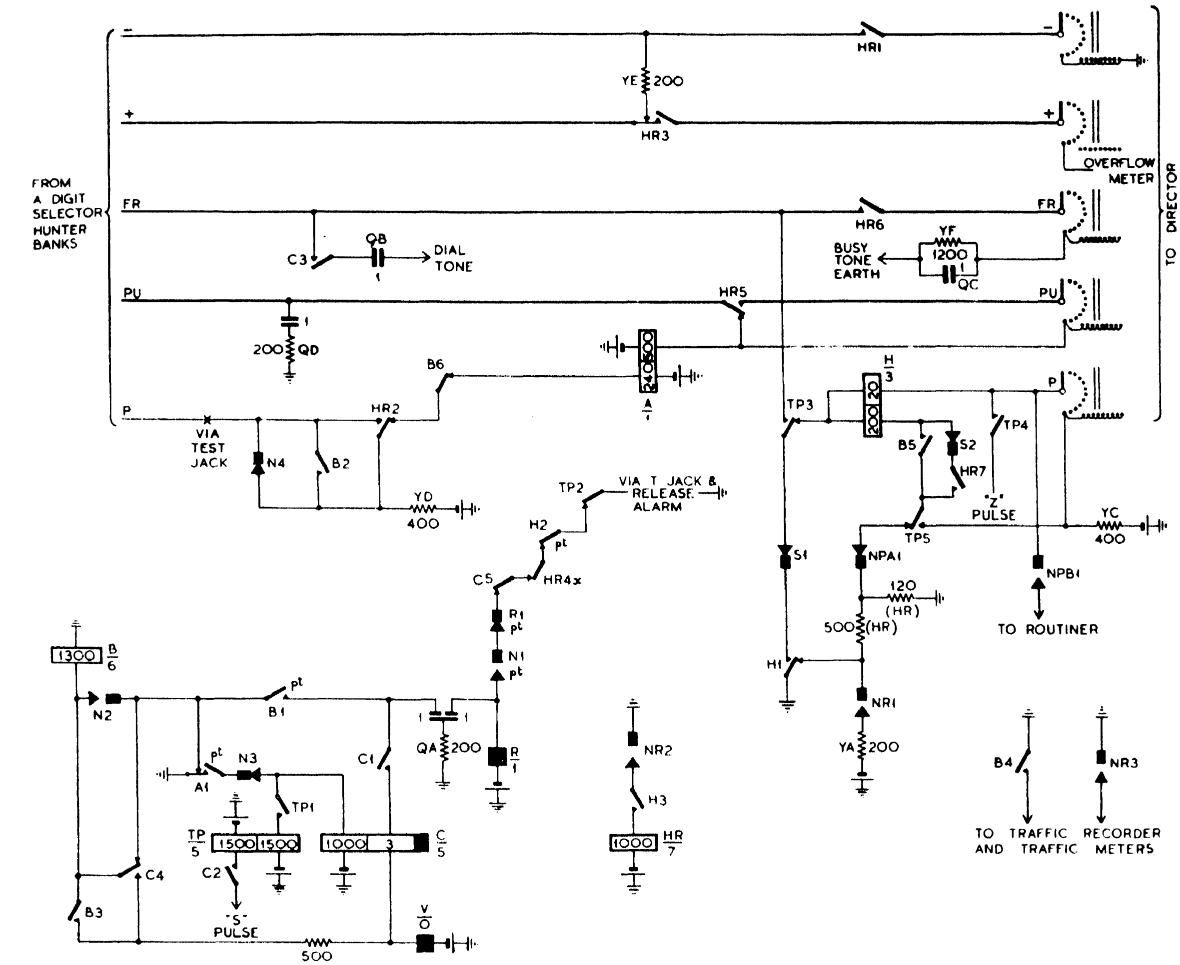


FIG. 396. A-DIGIT SELECTOR CIRCUIT

and is subsequently held over the *PU*-wire. The A-digit selector returns dial tone on the *FR*-wire as soon as it is seized by an A-digit hunter. The first train of impulses dialled by the subscriber steps the switch to the required level, and during the subsequent interdigit pause rotary search takes place to find a free director on the selected level. When a free director is found, the negative, positive, *PU*- and *FR*-wires are switched through to the director. On completion of pulsing out by the director, conditions are set up which release from the 1st code selector. ***A1*** operates relay *C* and ***C1*** prepares the impulsing circuit to the vertical magnet. ***C3*** connects dial tone via a 1 μF capacitor to the *FR*-wire for subsequent transmission to the calling subscriber at the 1st code selector. ***C4*** operates relay *B*, the contact being arranged so that, if *B* is operated manually when the circuit is not in use, the relay will not lock up (due to the earth at *A*1).

Relay *B* in operating completes the impulsing circuit to the vertical magnet at contact ***B1***, whilst

B2 connects holding battery to the *P*-wire in readiness for the operation of ***N4***. ***B3*** provides an alternative holding circuit for *B* independent of ***C4***. When the A-digit selector is the last choice of the grading, ***B4*** operates the traffic meter to register one call for each seizure of the selector. ***B5*** completes the circuit for the test relay *H* whilst ***B6*** disconnects the pre-operate circuit of *A* which now remains held on its 500 Ω coil from the earth on the *PU*-wire from the 1st code selector.

Vertical Stepping and Rotary Drive. The impulses from the calling subscriber's dial are repeated over the pulse wire (*PU*) from the 1st code selector as already described. These impulses are in turn transmitted to the vertical magnet at each release of *A*1. On the first vertical step, the off-normal springs (*N*) operate. ***N2*** short-circuits relay *B* on each release of *A*1 during impulsing, whilst ***N3*** disconnects the pre-operate circuit of *C* and the holding circuit of *TP* (see Forced Release Conditions).

At the end of the vertical train, *C* releases and at *C*5 completes the circuit for the rotary magnet. When the magnet is fully energized and the wipers are moved on to the first rotary contacts, ***R1*** breaks the operating circuit of the rotary magnet and an interacting drive circuit is provided until such time as *H* operates. At the first rotary step, the rotary off-normal contacts operate. Contacts ***NR1*** apply a 200 Ω battery to the switching relay circuit to provide the necessary release conditions during dual testing. Contacts ***NR3*** (in conjunction with ***B4***) provide a circuit for the traffic recorder.

Testing and Switching. On the first rotary step, relay *H* is applied to the *P* bank contact of the first outlet. If the outlet is free, battery on the *P*-wire is extended to *H* which operates to the 120 Ω earth and the 500 Ω earth (via *H*1) in parallel. ***H1*** completes a holding circuit for *H* and re-arranges the circuit conditions so that there is insufficient holding current if two *H* relays attempt to switch to the same director. ***H3*** operates the relief relay *HR* which at ***HR1***, ***HR3***, ***HR5***, and ***HR6*** extends the negative, positive, pulse, and forced release wires through to the director. ***HR2*** takes over the function of ***B2*** in readiness for the release of relay *B*. ***HR7*** maintains the circuit for the 200 Ω coil of relay *H* when *B*5 releases.

If the first outlet is busy, the release of the *R*1 springs again completes a circuit for the rotary magnet, and the wipers are stepped to the next contact as described above. If all outlets on the level are busy, the wipers will be rotated to the 11th rotary step, at which point the *S* springs are operated. Relay *H* operates to the 400 Ω battery on the 11th *P* contact and at ***H3*** operates *HR* as before. The *H* relay, in this case, remains held on both coils in series due to the disconnexion of the ***H1*** earth by springs ***S1***. The operation of ***S2*** also leaves the hold circuit of the *H* relay under the direct control of ***B5***. The operation of ***HR1*** extends earth from the 11th contact of the negative bank to hold relay *A* in the 1st code selector, whilst ***HR6*** applies busy tone from the similar contact on the *FR* bank. ***HR3*** extends the earth on the positive wire to operate the overflow meter. Relay *A* of the A-digit selector is now held over the *PU*-wire via the 11th rotary contact of the *PU* bank. The subsequent release of the selector is effected by the disconnexion of this earth from the *PU*-wire in the 1st code selector.

False Impulse Suppression. The circuit is arranged so that the selector will absorb a false initial digit of 1. In such circumstances relays *A*, *B*, and *C* are operated on the seizure of the A-digit selector, and a single initial impulse operates the vertical magnet to raise the wiper carriage to the first level. The normal post springs ***NPA1*** now operate and break the operating circuit of relay *H*. On the release of *C*, rotary drive takes place to restore the selector to its normal position. *C*1 prevents incorrect operation of the vertical magnet should the calling subscriber's cradle-switch be flicked whilst the switch is returning to normal after it has been stepped to level 1.

Forced Release. It has been seen that, when an A-digit selector is seized, relays *A*, *B*, and *C* are energized. ***C2*** completes the circuit of the *TP* relay which operates on receipt of the first *S* pulse. ***TP1*** provides a holding circuit for *TP* under the control of ***A1***. ***TP2*** disconnects the rotary release circuit to prevent re-seizure of the selector until *TP* is fully restored. ***TP4*** and ***TP5*** connect the *H* relay to the *Z* pulse wire. If the selector has not been stepped before the next *Z* pulse (30 sec later), relay *H* operates to the *Z* pulse and at ***H1*** connects earth via ***TP3*** to the *FR*-wire. The earth returned to the 1st code selector on the *FR*-wire causes the disconnexion of the A-digit selector holding earth on the *PU*-wire. Relay *A* now releases and at *A*1 gives one pulse to the vertical magnet. The subsequent release of *C* starts the rotary release movement.

Release. On a normal call, the holding battery for relay *H* is removed from the *P*-wire at the director when all digits have been transmitted. The release of *H* disconnects *HR*, and the restoration of *HR*2 removes the holding condition from the *P*-wire to release relay *K* in the 1st code selector. The holding condition on the *PU*-wire

is now removed, whilst the restoration of $H2$ and $HR4$ completes the rotary release circuit for the A-digit selector. It should be noted that $HR4$ is an "x" action contact to ensure that the release of the switch does not commence until the loop across the negative and positive wires has been re-connected at $HR3$.

Miscellaneous Features. A guard feature is provided to prevent calls being passed to an A-digit selector should the PU-wire be disconnected. It has been described above how relay A is pre-operated over the P-wire. **$A1$** operates B, and **$B6$** disconnects the initial operating circuit of A. If an alternative holding circuit for A over the PU-wire is not available, $A1$ releases to energize the vertical magnet and to short-circuit relay B. After a lag period, B also releases, and the holding battery is disconnected from the P-wire at $B2$. Relay K of the 1st code selector is now released, and the A-digit hunter associated with the selector steps to another outlet.

Outline of Director Circuit. We have seen that the director receives the B and C digits from the calling subscriber and then transmits a series of impulse trains to establish the call through the code selector and tandem selector stages. It is also necessary that the director should store the numerical portion of the called subscriber's number until such time as the transmission of the routing digits is complete. The circuit is necessarily somewhat complex and it is desirable to consider the general outline before proceeding to a detailed circuit description.

Fig. 397 shows the essential elements of a director circuit. The equipment includes:

(*a*) A 2-motion selector with 6 banks (the BC switch).

(*b*) Four uniselectors (M, C, D, U) which are required for the storage of the numerical portion of the called subscriber's number.

(*c*) A digit distributor by means of which the incoming impulse trains are transmitted in the correct sequence to the BC selector and the four numerical impulse storage uniselectors. The units impulse storage uniselector has no function until the last (7th) digit is dialled, and hence it is possible to use the early contacts of this uniselector bank as a digit distributor—thereby saving a uniselector mechanism.

(*d*) A send switch which controls the number of impulses in each digit transmitted by the director.

(*e*) A translation field consisting of suitably arranged terminal strips whereby it is possible to cross-connect the BC selector banks with the send switch banks to obtain the required translation.

(*f*) A control switch which determines the order in which the outgoing routing digits and the stored numerical digits are transmitted.

(*g*) An impulse machine which is common to a number of directors, and generates the necessary impulses for transmission by the director and also for digit control purposes within the director.

The director is seized by an earth on the pulsing-in wire, which operates the impulsing relay A. At the same time the circuit is guarded against intrusion by the application of an earth on the P-wire from the A-digit selector. The first impulse train (i.e. the B digit) causes contact $A1$ to release at each break impulse and to transmit an earth via relay C and the first contact of the $U4$ bank to the vertical magnet of the BC switch. The C relay operates at the first break of $A1$, and **$C1$** applies earth to energize the units uniselector. This switch is, however, of the reverse-acting type and does not move its wipers until the magnet is de-energized. This occurs at the end of the impulse train when $A1$ is operated for a prolonged period during the interdigital pause and the C relay releases. The release of $C1$ causes the wipers of the $U4$ arc to move to the second position so that the second impulse train (the C digit) is routed to the rotary magnet of the BC selector. The thousands, hundreds, tens, and units digits follow and are respectively routed to the appropriate uniselector magnets by the stepping of the $U4$ wiper after each digit.

It is, of course, not necessary to await the receipt of the complete series of impulse trains before commencing the transmission of the routing digits. Once the C digit has been received (i.e. when the BC selector is positioned on to a specific bank contact) the destination of the call is fully determined and it is then possible to commence the transmission of the routing digits. The 6 wipers of the BC selector are connected to the first 6 contacts of the control uniselector ($CN2$) so that earth is applied to the first wiper and this earth can be transferred to the 2nd, 3rd, 4th, etc., wipers in succession by the stepping of the control switch. The one hundred contacts of each bank of the BC selector are wired out to terminals on the translation field, i.e. there is a total of 600 terminals from the BC selector bank. The 10 working contacts of the send switch (arc 4) are also terminated on connexion tags which are multipled along the translation field and are also connected to the 10 working contacts of the 4 numerical storage uniselectors. The connexion tags are so arranged that it is possible to cross-connect any contact in each of the 6 BC selector banks to any desired send switch contact. These cross-connexions

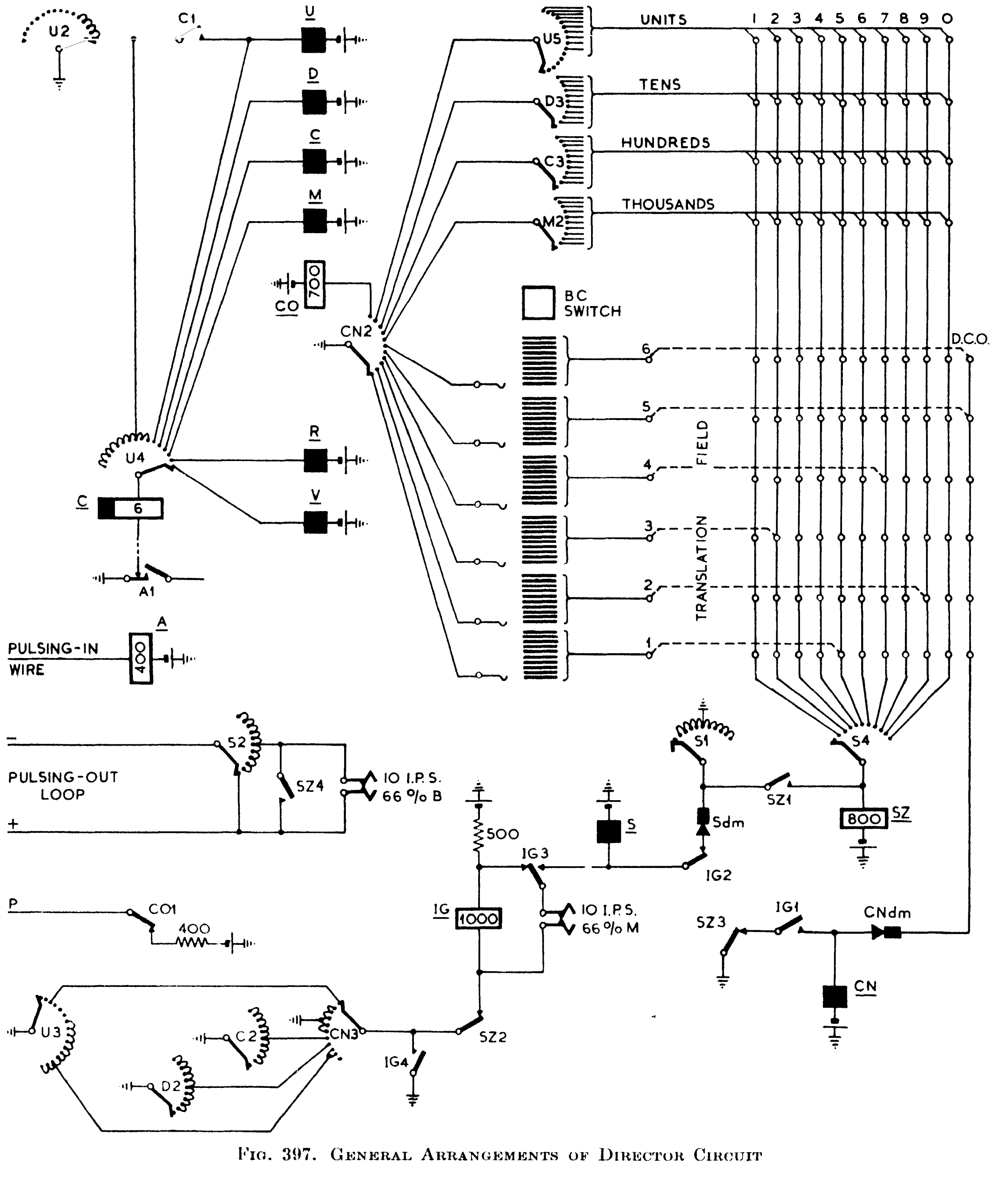


FIG. 397. GENERAL ARRANGEMENTS OF DIRECTOR CIRCUIT

determine the digits transmitted by the director on receipt of the *BC* code from the subscriber.

To illustrate, let us assume that the director in question is in the group serving the 2nd level of the A-digit selectors (i.e. the ABC level), and that, when a subscriber dials the three code letters CEN, the director is to transmit the digits 5927 to route the call to the required exchange. On such a call the wipers of the *BC* selector are stepped to the 6th contact of the 3rd level in response to the two final digits of the code (i.e. EN). In order to obtain the required routing digits, this contact of the 1st bank of the *BC* selector is cross-connected to the 5th terminal of the send switch bank. Similarly, the second digit is determined by the cross-connexion between the 6th contact of level 3 of bank 2 which is wired to contact 9 of the send switch bank. The 3rd and 4th banks are similarly cross-connected to give third and fourth digits of 2 and 7 respectively (the cross-connexions are indicated by the broken lines of Fig. 397). In this particular case only 4 impulse trains are required to route the call to its destination, but the director provides for up to a maximum of 6 routing digits. The 5th and 6th banks are therefore wired to a special *DCO* terminal which causes the control uniselector to pass on and commence the transmission of the numerical digits after 4 routing digits have been transmitted.

When the control switch is in its normal position, earth is extended via *CN*2, the first wiper of the *BC* selector, the cross-connexions on the translation field, to a predetermined contact of the send switch bank. The units uniselector steps to the 3rd contact at the end of the C digit, and earth is applied from the *U*3 arc and the first contact of the control switch arc 3 to the *IG* relay. A pair of impulse contacts is connected across this relay so that the operation of the relay is deferred until the impulse springs open. These impulse contacts are synchronized with a second set of impulse contacts which are connected to the pulsing-out loop, the two sets of contacts being arranged so that, when one set is closed, the other set is open, and vice versa. This circuit feature is necessary to prevent the transmission of a mutilated first impulse (see Chapter VI).

With the circuit arrangements shown it is impossible for the impulse springs to be connected to the pulsing-out loop except during the time when the springs are closed. The operation of *IG* extends (at ***IG*3**) the impulse springs to the driving magnet of the send uniselector. At the same time ***IG*4** provides an alternative earth for the stepping circuit independent of the control switch wiper. ***IG*1** energizes the control switch uniselector magnet, but the wipers of this switch do not step at this stage.

The wipers of the send switch are now driven at a speed of 10 steps per sec, and during the stepping of this switch, impulses are transmitted to line by the second pair of impulse contacts. (The short circuit across the pulsing-out loop is removed at the first step of the *S*2 wiper.) In due course the wiper of the *S*4 arc encounters the earth extended from the *CN*2 wiper via the *BC* selector bank 1 and the translation field. *SZ* operates over this circuit and locks via ***SZ*1**. ***SZ*4** now short-circuits the line impulse springs to terminate the first transmitted digit. ***SZ*3** breaks the circuit of the control switch driving magnet, and the wipers of this uniselector now step to the second position in readiness for the transmission of the next impulse train. ***SZ*2** cuts the operate circuit of the send switch driving magnet and at the same time allows relay *IG* to release. The restoration of *IG*2 completes a self-drive homing circuit for the send switch uniselector, and when the wipers reach the normal position the holding circuit of the *SZ* relay is broken at the *S*1 wiper. (As will be seen later, this homing circuit is in practice somewhat more complex in order to provide an interdigital pause of the required length.)

The restoration of *SZ*2 again applies the earth to the *IG* relay, and the circuit operation is repeated for the transmission of the second digit, i.e. the *SZ* relay operates when the *S*4 wiper encounters the earth extended over bank 2 of the *BC* selector. The same process continues until all the routing digits have been transmitted. At the end of the fourth digit it is necessary to arrange for the *CN* switch to pass over the 5th and 6th positions (which are not required for routing digits in this particular illustration) and to proceed with the transmission of the thousands digit. In order to provide the control switch step-on feature, any unused banks of the *BC* selector are connected to the *DCO* terminal so that earth extended by the *CN*2 wiper energizes the control switch driving magnet via its own interrupter contacts, *CNdm*.

When the *CN*2 wiper steps to the 7th rotary position, earth is applied to the thousands uniselector and thence via the send switch bank multiple to mark the *S*4 bank in accordance with the digit received by the director (i.e. there is no translation of the numerical digits). It is important that the re-transmission of the thousands digit should not commence until the thousands impulse train has been fully received in the director. This condition is possible in certain circumstances where the subscriber pauses between the exchange

code and the numerical digits, and the danger is accentuated when such a pause is accompanied by a single digit translation and a long thousands thence to initiate the send switch drive and the transmission of the impulse train.

Similarly it is important to ensure that the

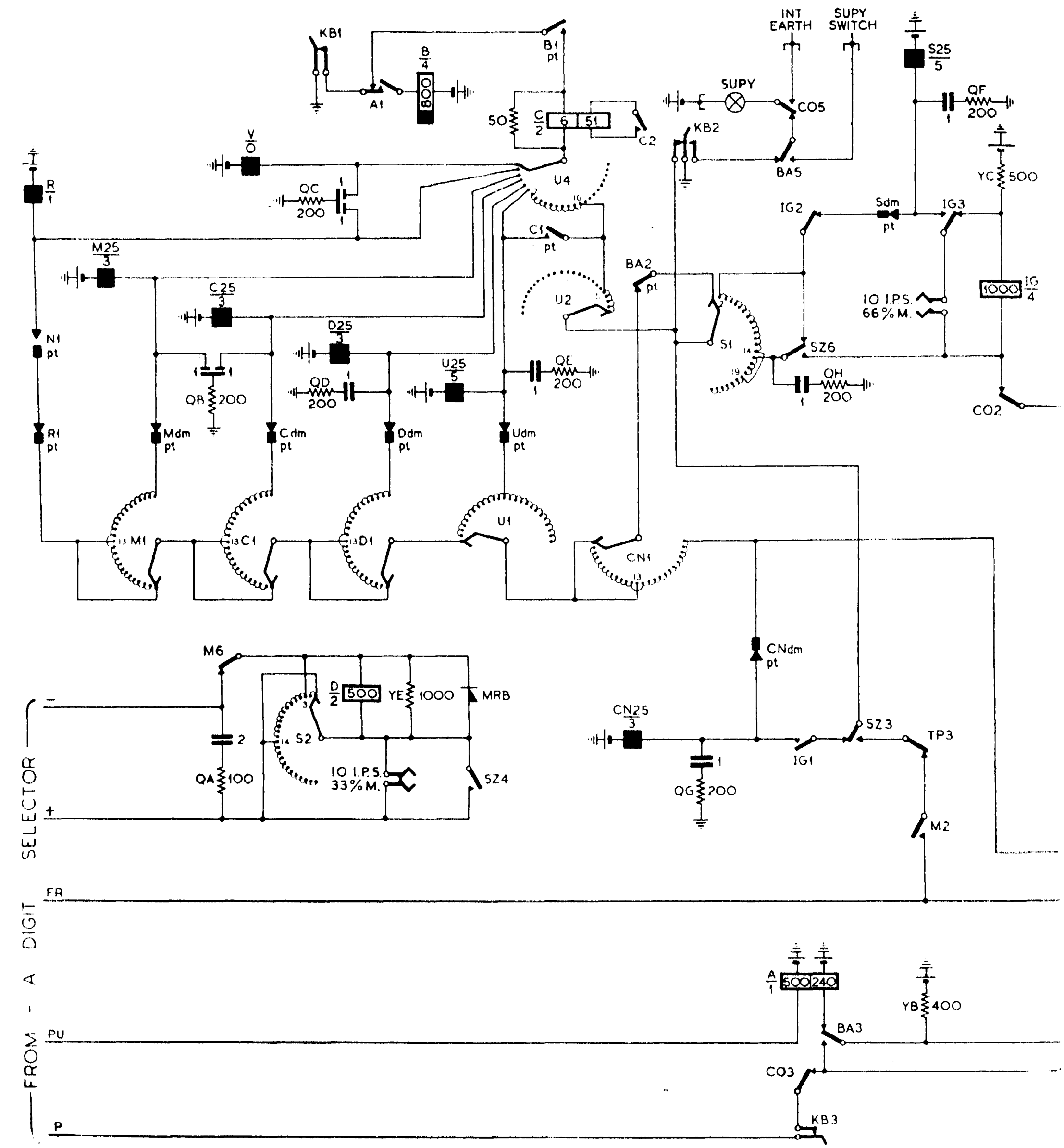
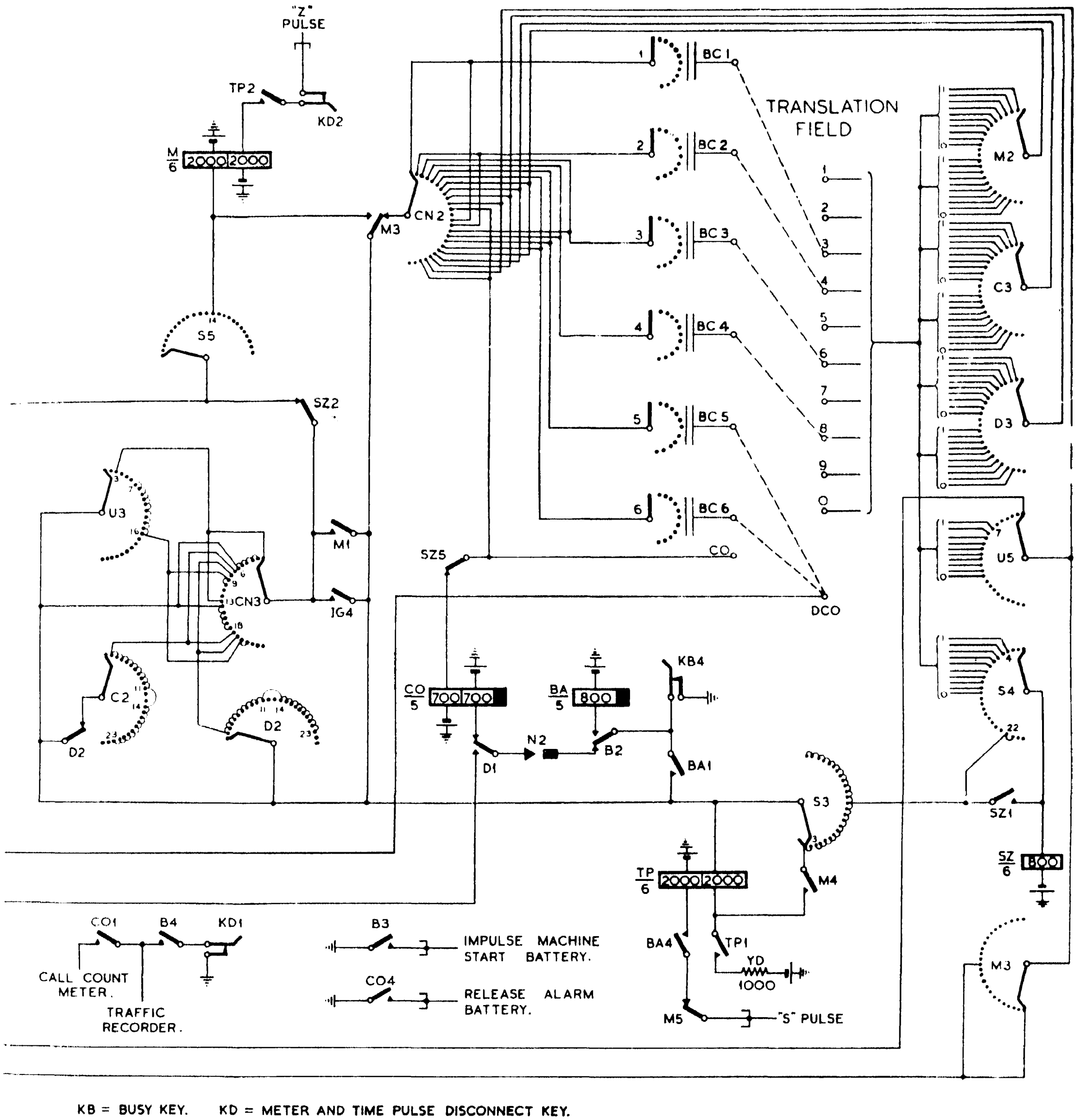


FIG. 398. COMPLETE

digit. To guard against such a mutilation, the transmission of the thousands digit is delayed until the first impulse of the hundreds digit is received (i.e. until the *C*2 wiper moves from its normal position). Earth is then extended via the 7th contact of the *CN*3 bank to operate *IG* and transmission of the hundreds digit does not commence until the incoming impulse train has been fully received. The transmission of the hundreds digit is therefore deferred until the tens uniselector moves off normal, i.e. until earth is extended to the *IG* relay from the *D*2 arc. For the same reason

the transmission of the tens digit is deferred until the units uniselector moves to its 7th rotary position (i.e. when the first impulse of the final train is received). When all digits have been transmitted, the control switch steps to the 11th rotary position and, at the *CN*2 arc, operates the *CO* relay. Contacts of the *CO* relay provide for the homing of the various switches and for the release of the director.

The Director. Fig. 398 gives the detailed connexions of the director. When the circuit is seized relay *A* operates to the earth on the *P*-wire via the home contacts of uniselector arcs *M*3 and *U*5. *A*1 operates *B* which at *B*1 prepares the circuit for repeating the impulses to the *BC* switch and uniselector magnets. *B*2 energizes *BA* whilst *B*4 operates the traffic recorder. *B*3 applies an earth to the start wire of the impulse machine.



Director Circuit

***BA*1**, in operating, applies an earth to various wipers of the storage uniselectors. ***BA*2** disconnects the homing circuit of the control and storage uniselectors and the release circuit of the *BC* switch. ***BA*4** connects the *TP* relay to the *S* pulse wire whilst ***BA*5** completes the circuit for the director supervisory lamp.

The director is now prepared to receive the digits dialled by the calling subscriber. The incoming impulses are received by the *A* relay over the *PU*-wire and, at *A*1, the impulses are repeated (via the *C* relay and *U*4 arc) to each of the magnets in turn.

Reception of Impulses. The vertical magnet (*V*) operates to the first train of impulses and relay *C* operates during the impulse train. ***C*1** energizes the units uniselector driving magnet whilst ***C*2** short-circuits the 51 Ω coil of relay *C* to make the relay slow-to-release. During the interdigit pause, *C* releases and *C*1 breaks the circuit of the units uniselector drive magnet, thereby causing the wipers to be stepped to the next contact. The second train of impulses received in the director is now routed via the second contact of arc *U*4 to the rotary magnet of the *BC* switch, and at the end of the second train, *C* again releases to cause a further step of the units switch. This action continues and the incoming trains of impulses are routed in turn to the *BC* switch vertical magnet, the *BC* switch rotary magnet, the thousands uniselector, the hundreds uniselector, the tens uniselector and finally the units uniselector.

Pulsing Out. After the receipt of the C digit and the consequent operation of the *BC* switch rotary magnet, earth is extended via arc *U*3, the home contact of *CN*3, *SZ*2, and *CO*2 to operate relay *IG*. ***IG*1** energizes the control switch (*CN*) drive magnet, whilst ***IG*4** provides an alternative holding circuit for *IG* from the common earth. ***IG*3** completes a circuit for the send switch (*S*) driving magnet via the 66 per cent make impulse machine contacts. At the second step of the send switch wiper, *S*2 breaks the short circuit across the negative and positive outgoing wires in order to allow impulses to be transmitted to line by the 33 per cent make impulsing springs.

In due course relay *SZ* operates when the *S*4 wiper encounters a marking earth on its bank. As explained in earlier paragraphs, the position of this earth is determined by the positioning of the first *BC* wiper. ***SZ*1** provides a hold circuit for *SZ* independent of the *S*4 bank. ***SZ*2** disconnects the circuit for *IG* and the stepping circuit for the *S* switch driving magnet. ***SZ*3** breaks the circuit of the control switch driving magnet which was energized by the operation of ***IG*1**. ***SZ*4** short-circuits the line impulsing springs to prevent further impulses being transmitted. ***SZ*5** prevents the operation of relay *CO* until the end of the interdigit pause subsequent to the sending of the last train of impulses.

Relay *IG* in releasing completes the homing circuit for the send switch at *IG*2. The send switch now self-drives via its own interrupter contacts until it reaches contact 15. At this point the homing circuit is broken on the *S*1 bank and earth is applied to the *IG* relay and the 66 per cent make impulse springs via contact ***SZ*6**. Relay *IG* re-operates at the first break of the impulse contacts and ***IG*3** now completes a circuit for the *S* switch to step under the control of the impulse springs in order to provide the required intertrain pause. At contact 19 the homing circuit is re-established at the *S*1 bank, and the *S* switch drives under the action of its own interrupter contacts to its home position, relay *IG* being released when the *S*1 wiper leaves the 18th contact. The return of the *S*3 wiper to its home position releases relay *SZ* and the sequence of operations is repeated for each of the following impulse trains.

Release. Relay *CO* operates from the earth on the *CN*2 arc when the control switch steps to the 11th rotary position, i.e. when the last train of impulses has been sent out and relay *SZ* has been released. ***CO*1** operates the director call-counting meter. ***CO*2** breaks the circuit of relay *IG* to prevent the sending out of any further impulses. ***CO*3** removes the holding battery from the *P*-wire to release the A-digit selector. ***CO*4** completes the release alarm circuit whilst ***CO*5** replaces the full earth connexion to the supervisory lamp by an intermittent earth in order to change from a continuous glow to a flashing signal.

Relay *A* releases when the earth is disconnected from the *PU*-wire by the release of the A-digit selector and at *A*1 releases relay *B*. *B*2 in turn releases relay *BA* and provides a temporary alternative holding circuit for relay *CO*. *BA*1 disconnects the earth from the various uniselector wipers, whilst *BA*2 completes the homing circuit for the *CN*, *U*, *D*, *C*, and *M* uniselectors, all of which now drive to their home contacts. When all uniselectors are normal, earth is connected to the rotary magnet via the *R*1 contacts, and the wiper carriage of the *BC* switch is rotated until it is clear of the banks. The shaft then restores to its normal position and the rotary magnet circuit is broken at *N*1. The disconnexion of *N*2 now releases *CO* which in turn restores the *P*-wire testing-in circuit at *CO*3.

Pulsing-out Suspension Feature. In some circumstances it may be necessary to suspend the pulsing-out of the numerical digits until the distant equipment is ready to receive the impulse trains. Such conditions may, for example, occur on calls to a C.C.I. manual exchange (q.v.) when it is not possible to obtain access to a free "coder" in the time available between the transmission of the last routing digit and the first numerical digit.

Relay *D* in the director circuit is connected so that it does not operate on normal calls due to the shunting effect of rectifier *MRB*. If it is desired to hold up pulsing-out, the line current is reversed at the distant apparatus and relay *D* now operates. ***D*2** withdraws the earth from the *C*2 wiper so that relay *IG* cannot operate for the thousands digit. ***D*1** connects earth to the *FR*-wire if the subscriber clears during the hold-up condition. The release of the 1st *C* selector then releases *D*.

Forced Release. If a subscriber holds a director and does not complete dialling within a period of from 30 to 60 sec, forced release conditions are set up. Relay *TP* operates to the first earth on the *S* pulse wire and at ***TP*1** provides a holding circuit to the common earth wire of the director. The next *Z* pulse now operates relay *M* via ***TP*2**. ***M*1** provides an earth to operate relay *IG* and to step the send switch magnet. ***M*3** disconnects the marking earth from the *CN*2 wiper and on its make contact provides a holding circuit for relay *M*. ***M*4** short-circuits the holding coil of relay *TP* to ensure the release of that relay when the sender uniselector reaches the home contact. Similarly ***M*5** disconnects the *S* pulse wire to prevent further operation of *TP*. ***M*6** breaks the holding loop to the 1st code selector.

The operation of ***M*1** and the subsequent operation of ***IG*3** cause the send switch to step, and when the *S*4 wiper reaches contacts 22 and 23 a circuit is completed to operate relay *SZ*. ***SZ*1** provides a hold circuit for *SZ* as before until such time as the *S*3 wiper returns to normal. ***SZ*2** releases *IG* and disconnects the stepping circuit of the *S* switch which now self-drives via contact *IG*2. ***SZ*3** connects earth to the *FR*-wire to operate relay *M* in the 1st code selector. The earth extended on the *PU*-wire is now disconnected in the 1st code selector and relays *A*, *B*, and *BA* in the director release. *B*2 operates *CO* whilst ***CO*3** disconnects the *P*-wire to release the A-digit selector. It should be noted that, if relay *M* (director) is operated whilst the *S* switch is off-normal, relay *TP* does not release until the switch reaches its home contact and the earth is then applied to the *FR*-wire by the release of *TP*3.

Spare Codes. If a subscriber dials a spare code, relay *IG* is operated by the earth applied via the third contact of *U*3. *IG* in operating steps the send switch via ***IG*3**, but as no marking earth is encountered on the *S*4 arc the switch continues to step until the wipers reach contact 14. At this point an earth is applied via arc *S*5 to operate relay *M*. *M* in operating locks at ***M*3** whilst ***M*2** prepares a circuit for the subsequent connexion of an earth to the *FR*-wire when ***SZ*3** operates. The *SZ* relay is energized when the send switch steps to contact 22 (arc *S*4) and holds at ***SZ*1**. ***SZ*2** releases *IG* and disconnects the stepping circuit for the *S* switch which now drives via its own interrupter contacts through *IG*2 and the *S*1 bank. ***SZ*3** connects earth to the ***FR***-wire to establish release conditions.

Director with Manual Board Facilities. When a subscriber on a director exchange dials "0," the A-digit selector is stepped to the 10th level, and the call is switched to a director. The directors on this level must be arranged so that they will automatically send out the appropriate routing digits immediately they are seized, i.e. without waiting for further digits to position the *BC* switch. The holding time of a director on a manual board call is of the order of 2 or 3 sec, i.e. it is held only sufficiently long to transmit one or two trains of impulses necessary to step the code selectors. This very short holding time, coupled with the comparatively small volume of traffic, does not justify the provision of a separate group of directors for the "0" level. In practice, the "0" level is coupled with one or two other levels to provide a common director group. This necessitates a discriminating signal so that any director in the common group will pulse out automatically if it is seized from the "0" level.

"0" level discrimination is obtained simply by arranging that the — and + wires are reversed on the "0" level of the A-digit selectors. This reversal causes relay *D* in the director to operate immediately the circuit is seized on an "0" level call. The directors which serve the "0" level are provided with an additional relay (*MB*), Fig. 399. This relay is energized by the operation of ***D*1** on the seizure of the director, and holds via ***MB*5** to the common earth of the director circuit. The four other contacts of the *MB* relay (***MB*1**, ***MB*2**, ***MB*3**, and ***MB*4**) by-pass the first four wipers of the *BC* selector, thereby extending the control switch to the translation field and thence to the send switch banks. By this means, up to a maximum of four trains of impulses can be transmitted automatically when the director is seized for a manual board call. Contact ***MB*6** operates relay

CO to release the director when the control switch has stepped to contact 5. A further contact of the *MB* relay is provided to operate relay *IG*

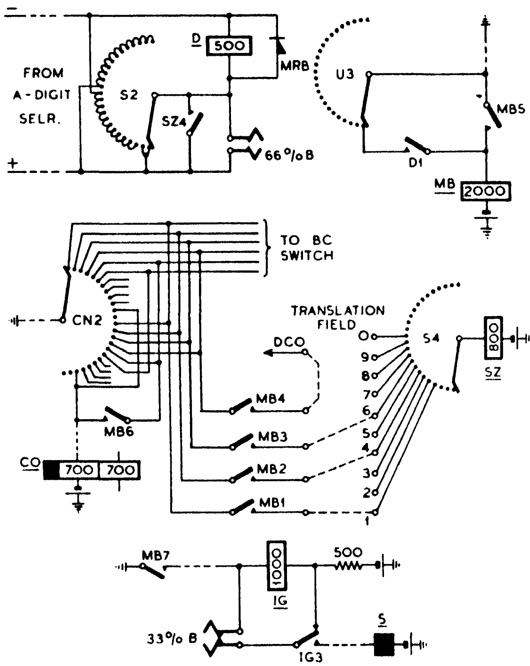


FIG. 399. ADDITIONAL FEATURES ON MANUAL BOARD DIRECTOR

and hence to establish the correct conditions for the transmission of the impulse trains. A final contact of the *MB* relay (not shown in Fig. 399) is inserted in the *BC* switch *R* magnet circuit to prevent the operation of the rotary magnet (and a possible mutilation of the routing trains) if the subscriber should continue to dial after the initial digit "0." This same contact also prevents irregular operation should the calling subscriber clear down prematurely.

It should be noted that the *MB* relay cannot be operated after the units digit uniselector has moved from normal (i.e. after the receipt of the first impulse train). A later operation of *D* under director "hold-up" conditions does not, therefore, result in the operation of relay *MB*.

Relay Type Director. Uniselectors and 2-motion selectors are designed primarily for use in the normal switching train of an automatic exchange. When these mechanisms are used in a director circuit, they are subject to much greater wear and tear, with the resultant heavy charges for maintenance and replacements. On an average, the holding time of a director is of the order of 20 sec, and during this period the send switch may be driven over its bank some 7 or 8 times. The directors (especially the first choices) are in use for a large part of the day, and the ratchet and pawl system of the send switch may make well over 500 000 steps in the course of a 24-hour period. The remaining switches of the director are somewhat less heavily worked, but nevertheless the number of operations is very much greater than when the switches are used in the conversational selectors of a switching train.

A new type of director (known as a relay director) has recently been developed in an endeavour to

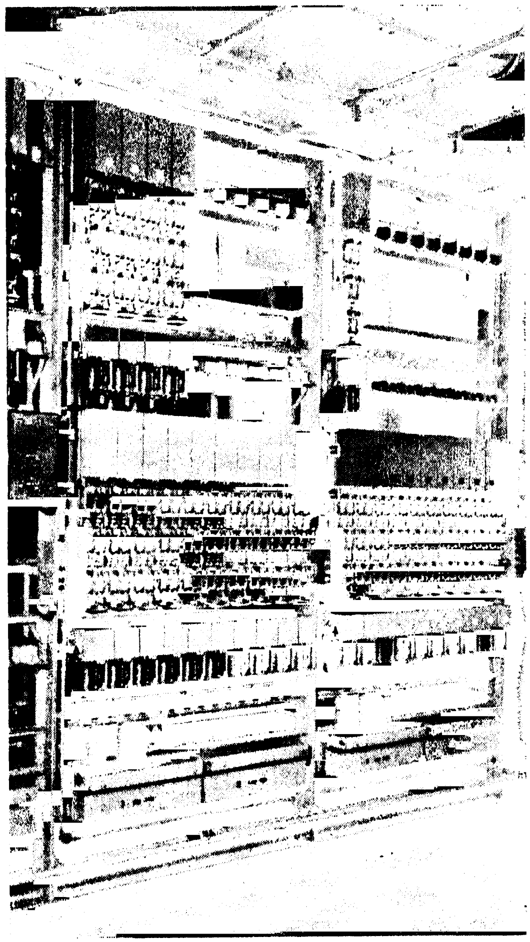


FIG. 400. DIRECTOR RACKS

reduce the maintenance charges on this item of equipment. In the new director, all impulse counting and storage is effected by the use of standard 3000 type relays, and a motor uniselector

is used to obtain the translations. At the time of writing, this director is on field trial and has not yet been adopted for general application.

1st Code, A-digit Selector and Director Racks. The 1st code selectors, together with their associated A-digit hunters, are mounted on standard 4 ft 6 in. wide racks. The 10 ft 6½ in. type rack has a capacity for 40 selectors, whilst the smaller rack is limited to 30 selectors. The selectors are, of course, arranged in shelves of 10 (i.e. there are 4 shelves of 1st code selectors on a 10 ft 6½ in. rack). The A-digit hunters are concentrated at the centre of the rack on 3 shelves of suitable design. These shelves also accommodate the routiner access uniselectors, etc.

The A-digit selectors are mounted on a separate 4 ft 6 in. rack, each rack having a capacity for 7 shelves of 10 A-digit selectors. The miscellaneous relays required for forced release, etc., are mounted on small units at the front of the right-hand vertical. In some small exchanges there are insufficient A-digit selectors to justify the provision of a complete rack. In these circumstances it is usual to provide a mixed rack of A-digit selectors and 2nd code selectors.

For convenience of handling, the director circuit is divided into three separate parts:

Part 1—The various relays and uniselectors.
Part 2—The *BC* selector.
Part 3—The translation field.

A 10 ft 6½ in. rack (4 ft 6 in. wide) will accommodate 20 complete directors together with a pair of impulse machines. The equipment is located on 4 shelves as shown in Fig. 400. The lowest shelf (A) accommodates 10 *BC* switches, whilst shelf B provides for the associated relay and uniselector groups. The arrangement is repeated for shelves C and D. The translation field is fixed by suitable brackets at the rear of the rack in a convenient position between the relay group and the *BC* switch. Covers are provided to protect the translation field against damage and dust.

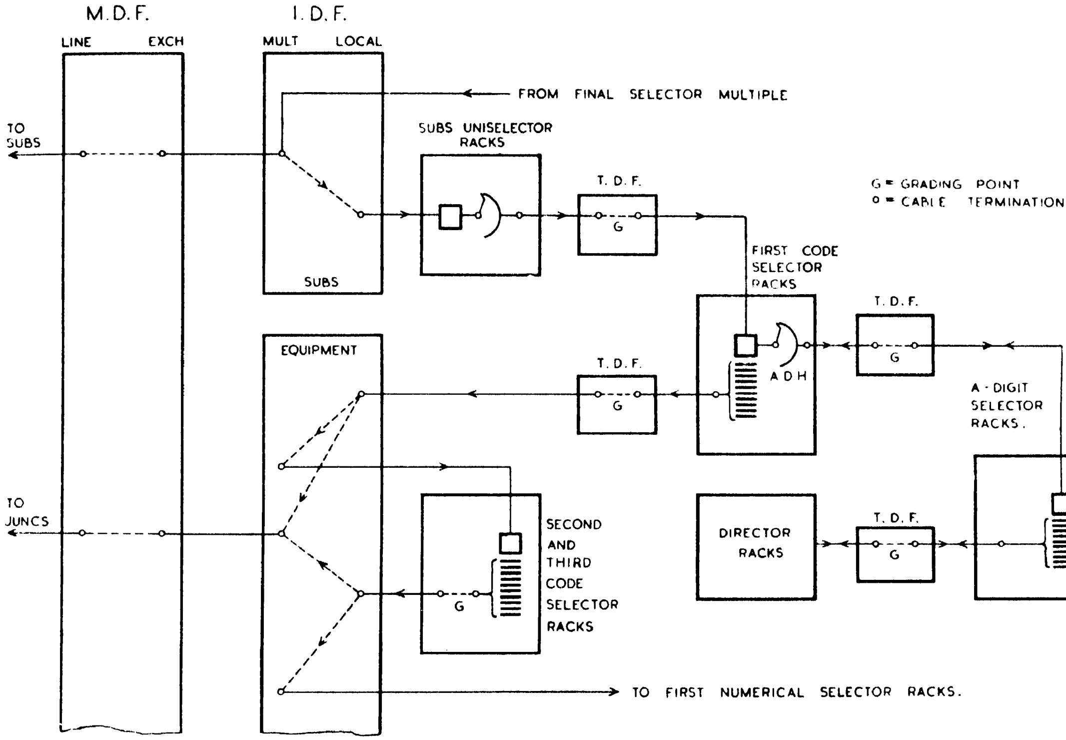


FIG. 401. CABLING SCHEME OF CODE SELECTORS, A-DIGIT SELECTORS, DIRECTORS, ETC.
(For cabling of numerical and final selectors—See Fig. 175)

Cabling Scheme. Fig. 401 shows the general cabling scheme of the code switching stages of a director exchange. In accordance with the usual practice, the subscribers' lines appear on the multiple side of the I.D.F. where they are cross-jumpered to the uniselector terminations on the local side of the frame. The bank multiple of each

shelf of uniselectors is commoned as required to other shelves, and tie-cables are led to the uniselector T.D.F. The outlets are graded at this point, and the gradings are jumpered to outgoing connexion strips leading to the 1st code selector racks. On this rack, the A-digit hunter banks are terminated on connexion strips, from which the circuits are cabled to a convenient T.D.F. which provides a grading point for the outgoing trunks of the A-digit hunters. Cabling is provided from the T.D.F. to each A-digit selector. The A-digit selector outlets are also returned to a T.D.F. for grading to the directors.

The 1st code selector levels are terminated on connexion strips behind the banks, and after suitable grouping are cabled to the local side of the equipment I.D.F. via a T.D.F. grading point. The 2nd and 3rd code selector racks of a modern exchange are identical with the group selector racks of a non-director exchange. They are provided with grading facilities at the rear of the rack with tie-circuits to the I.D.F. local. The trunks from code selector levels are now taken either to outgoing junctions or to local 1st numerical selectors, as required.

The cabling arrangements of the numerical and final selectors are as shown in Fig. 175.

Application of Director System. The director system is used in London, Birmingham, Liverpool, Manchester, and Glasgow, and at the present time is being introduced in Edinburgh. The London director scheme includes all exchanges within a circle of 12½ miles radius from Oxford Circus. The Birmingham, Glasgow, Liverpool, and Manchester systems comprise all exchanges within a circle of 7 miles radius from the centre. It is intended that these areas will, in due course, be extended to embrace the larger exchanges up to a 9½-mile radius from the centre. Generally speaking it is the policy to install director equipment when the total subscribers' multiple required at the 30-year period is greater than 60 000 lines. In some cases non-director type plant with a 5-digit numbering scheme will suffice for a 20-year period but will not meet the 30-year requirement. In such cases non-director equipment may be installed, but a special study of all border-line cases is made in order to determine whether or not it will be better to provide director plant at the outset.

EXERCISES XIII

1. Discuss the advantages obtained by the use of a director system as compared with a non-director system in a large area, such as London, with a high telephone density. (*C. & G. Telephone Exchange Systems II*, 1948.)

2. Describe, with the aid of simple diagrams, how manual hold facilities are provided in a 1st code selector circuit. What happens in a 1st code selector if the calling subscriber commences to dial prior to the receipt of dialling tone, i.e. before a free A-digit selector has been found?

3. State the sequence in which the various switches are seized and operated when a subscriber dials A, B, and C digits into a director exchange. Show, with the aid of a diagram of the "private wire" circuit, how the director causes the release of the A-digit hunter and the A-digit selector after pulsing-out has been completed in a normal call. (*C. & G. Telephony, Grade III*, 1944.)

4. Enumerate the functions of an A-digit selector, as employed in a director exchange.

In what circumstances is it practicable in a director area to connect together two or more of the A-digit selector levels, and what advantage is gained by doing so?

Explain, with the aid of a diagram of the circuit elements concerned, what happens if the vertical magnet in an A-digit selector receives one impulse only. (*C. & G. Telephony, Grade III*, 1942.)

5. Explain the factors which determine the allocation of outgoing junction routes to the levels of code selectors in a director exchange.

6. Draw a circuit diagram of the pulsing-out element of a director, including the connexions to the impulsing machine and the devices for guarding against an incomplete first impulse. If the instant of opening of the "loop" spring contacts of the impulse machine is taken as zero time, and the signal to start impulsing-out the first train is given 10 msec later, show in tabular form the sequence of operations in the circuit as the machine contacts open and close, i.e. at 0, 66, 100, 166, 200, 266 msec, and so on, up to the completion of transmission of the first train, which should be assumed to be the digit "2." (*C. & G. Telephony, Grade III*, 1946.)

7. By reference to the circuit diagram (Fig. 398) draw a diagram of that part of the director circuit which sets up conditions for the return of number-unobtainable tone when a "spare code" is dialled; describe the circuit operations involved.

Explain, briefly, under what circumstances a fault in a director may cause number-unobtainable

tone to be returned incorrectly, and enumerate the possible points at which such a fault may exist. (*C. & G. Telephone Exchange Systems II*, 1948.)

8. Explain the functions of the "units" register in a director. Give a diagram of the circuit elements necessary to illustrate your answer. (*C. & G. Telephony, Grade III*, 1947.)

9. Show how a director circuit provides for the transmission of the necessary routing digits when a calling subscriber dials "0" to obtain the attention of the automanual switchboard operator.

10. Give a sketch to show the general cabling arrangements of a director exchange. Show the points on the diagram where grading facilities may be provided.

CHAPTER XIV

THE UNIT AUTOMATIC EXCHANGE NO. 12

The merits of automatic switching in rural areas have already been considered at some length in Chapter I. The problem of providing telephone service in such areas is primarily an economic one. In rural communities the total number of subscribers is usually small and the calling rate is low. The total revenue is therefore comparatively small, and this must be balanced against the annual charges of the exchange equipment and of the long subscribers' lines and long junction circuits to the main telephone network.

Apart from the service advantages, automatic switching can be justified in a rural area only if the system is designed to eliminate the local telephonist. The automatic plant should also be capable of working satisfactorily in unheated buildings—the cost of heating a small exchange building would absorb a considerable proportion of the small revenue. It is, moreover, important that the equipment should require a minimum of maintenance attention since, in most cases, a considerable journey may be necessary to visit the exchange from the nearest centre which can justify the stationing of a maintenance engineer. A high degree of standardization of the various rural units is clearly an advantage (one man may have to maintain a large number of small rural exchanges). Similarly, the electrical energy consumption must be small, especially when the equipment has to work in districts where there are no public supply mains. Finally, the rural automatic exchange equipment should, as far as possible, be designed to minimize the amount of work on site during installation.

To meet the needs of rural and small urban areas, three standard types of exchange have been introduced. Each exchange equipment consists of a number of standardized units, each of which is, as far as possible, self-contained. The exchanges are therefore commonly known as *Unit Automatic Exchanges* (abbrev. U.A.X.). The three types are designated:

U.A.X. No. 12, with a maximum capacity for 100 subscribers' lines and junctions.

U.A.X. No. 13, with a maximum capacity for 200 subscribers' lines. (The U.A.X. No. 13 can, in certain cases, be used to serve an exchange area where the ultimate capacity does not exceed 400 lines.)

U.A.X. No. 14, with a maximum capacity for 800 subscribers' lines. (Like the U.A.X. No. 13, it is possible, exceptionally, to increase the nominal maximum capacity.)

It is intended that U.A.X.s 12 and 13 shall be located in unheated buildings, and the equipment is housed in special airtight units. A U.A.X. 14 exchange is built up of unit type apparatus racks, but, since the building is heated, the racks are of open construction similar to those of a non-director or director exchange.

The U.A.X. 12 is described in the following paragraphs of this chapter. The remaining two types are considered in later chapters.

Facilities Provided by U.A.X. 12. The principal facilities provided by the U.A.X. 12 are as follows:

(1) Dialling, ringing, busy, and number unobtainable tones are given under the same conditions as in the standard non-director equipment.

(2) There is a total multiple and linefinder capacity for 100 subscribers' lines and junctions.

(3) A 3-digit numbering scheme (i.e. 200–299) is used. Certain of these numbers are, however, not available for subscribers, due to the allocation of the selector bank contacts for parent exchange junctions and for routes to adjacent exchanges.

(4) A common group of junctions is provided to the parent exchange and is trunked from the 9th level of the U.A.X. selectors. This route caters for traffic to the parent exchange manual board (dialling code "0") and also for traffic to the automatic exchange at the parent centre (dialling code "9"). When there is no direct route to the parent exchange, the parent manual switchboard can be reached via a tandem centre by dialling "0" once only. The number of outlets from the U.A.X. to the parent exchange is limited to 8, owing to the presence of the fault test number (299) and the service telephone (290) on the last two contacts of level 9.

(5) Levels 3 to 8 inclusive can be used for obtaining access (by single-digit dialling codes) to adjacent exchanges. If (as is usual) a route does not require a complete level, it is possible to accommodate subscribers' lines on the spare contacts of the level.

(6) Facilities to cater for P.B.X.s of up to 10 lines are provided throughout the subscribers' numbering range.

(7) Any number can be allocated to a coin-box line. Coin-box calls appear on a separate lamp and

jack at the parent manual switchboard, a special signal being forwarded over the parent junction to effect discrimination.

(8) Multi-metering up to 4-unit fees is available, and the equipment provides route restriction and discriminating facilities. Coin-box lines are barred access to multi-fee routes.

(9) Two-party lines—without secrecy or meter discrimination—can be connected, but there is no provision for rural party lines.

(10) All incoming junctions terminate on the early choice contacts of the linefinders in exactly the same way as the subscribers' lines. Dial tone is given to the caller and, if premature dialling occurs, busy tone and flash are returned.

(11) The trunking arrangements are such that, if the first choice outlet on the parent exchange route is out of order, the call will be routed via the second choice on a second attempt.

(12) Manual hold is provided on "0" level calls to the parent exchange. Manual hold is also provided on calls to non-parent manual exchanges and certain automanual switchboards.

(13) Facilities are not provided for the handling of through traffic, i.e. a U.A.X. 12 is invariably a terminal exchange.

(14) Trunk offering facilities are available on any incoming route.

(15) Overflow meters are provided on the linefinders and selectors, and on each group of junctions.

(16) There is no fault alarm extension system, but a fault test number on the U.A.X. is arranged to return suitable tones to indicate whether any fault conditions exist.

(17) If any circuit is seized by a line with an earth fault (e.g. earth on B), the selector is released immediately and the fault condition is reverted to the subscriber's line circuit (which is busied until the fault condition is cleared). Similarly, forced release is applied after a time pulse period (of from 1 to 2 min) under permanent loop or called-subscriber-held conditions and also (after from 2 to 6 min) when a spare code is dialled.

Trunking Scheme. The general trunking arrangements of a U.A.X. 12 are shown in Fig. 402. The subscriber's line circuit consists of three relays, and is wired to the banks of double-hunting (i.e. 50-point) uniselector linefinders. The linefinders are arranged to home after every call, and each linefinder is directly connected to a 100-outlet 2-motion selector. In a fully equipped exchange the lines are divided into two separate 50-line sections, each served by a different group of linefinders and 2-motion selectors. One allotter switch is provided per linefinder group.

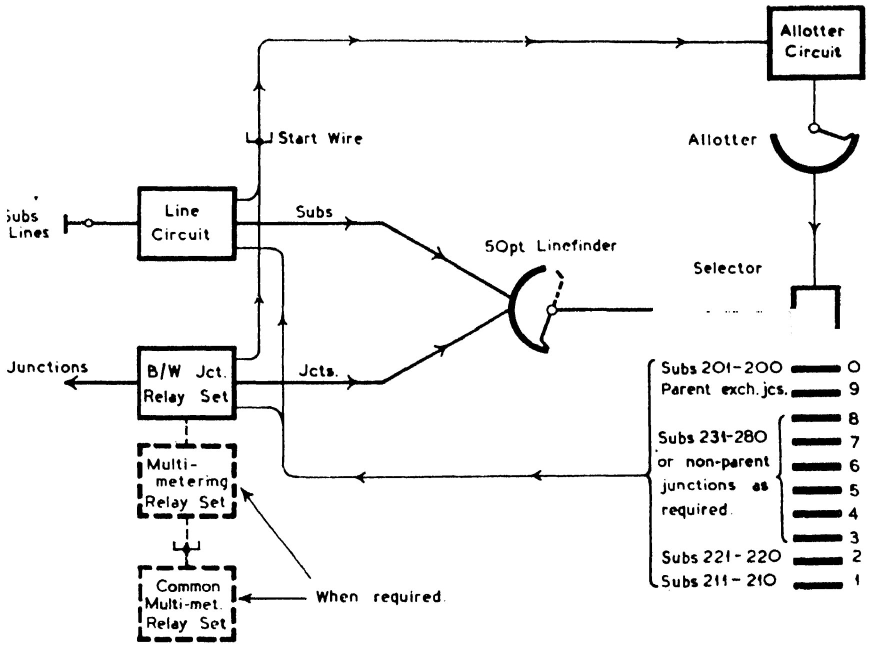


FIG. 402. GENERAL TRUNKING ARRANGEMENTS OF U.A.X. 12

The incoming side of the bothway junction relay sets is also terminated on the linefinder banks, and incoming junction calls are handled by the automatic equipment in exactly the same way as a local call. To minimize the linefinder hunting time, the junctions are terminated on the early choice outlets of the bank. This feature is of particular importance on incoming calls obtained via a selector level at a distant exchange. In such cases there may be very little left of the interdigit pause when the call is extended to the U.A.X.

The first digit (2) of a local number is used for discriminating between local and junction calls. This digit is absorbed by the 2-motion selector after discrimination, and the selector then steps to the two final digits of the called subscriber's number. The digit 9 is used to gain access to an incoming selector at the parent exchange if the

latter is automatic. The dialling of the digit 0 routes the call over the same junction group (i.e. via level 9), but a discriminating signal is passed over the junction to switch the call to the parent exchange operator. The provision of this common group of junctions increases the traffic carrying capacity per junction, and results in material economies of plant. Non-parent junction routes (when required) can be accommodated on levels 3 to 8 inclusive, any spare positions on these levels being available for local subscribers' numbers.

The multi-metering equipment is contained in a relay set associated with each bothway junction circuit. Where there is a large number of dialling codes, it may be necessary to provide an auxiliary multi-metering relay set which is common to all the outgoing junctions at the exchange.

Coin-box calls make use of normal subscribers' line circuits and are routed through the common group of linefinders and selectors. A discriminating signal provides a distinctive calling condition to the parent exchange operator on coin-box calls. The same discriminating signal also bars coin-box users from obtaining access to exchanges beyond the unit-fee radius of the U.A.X.

Outline of Operation. The allotter switch is normally standing on contacts which give access to a free connecting link. When a subscriber lifts his receiver to originate a call, the allotter circuit causes the linefinder to search for the calling line, and in due course the caller is extended to the associated selector from which he receives dial tone. The allotter circuit is in use only during the searching time of the linefinder, after which it steps on to pre-select another free link circuit in readiness for the next call. The circuit arrangements are such that a different linefinder is seized each time a call is originated, thereby preventing a serious interruption of service which may otherwise occur should one of the linefinders or selectors become faulty.

In a small exchange of this type, it is important that short-circuited lines or the accidental removal of receivers should not be allowed to engage the common switching equipment. It is arranged, therefore, that, if a caller fails to dial within a period of from 1 to 2 min, the selector and linefinder are released, and the subscriber remains locked to his line circuit until the loop is removed.

If a local call is required, the dialling of the initial digit 2 causes the selector to step to the second level, to operate local discriminating relays, and then to release. The second digit steps the selector vertically, whilst the third digit completes the rotary motion. If the required line is free, ringing current is transmitted and ringing tone is returned to the caller. If, on the other hand, the line is busy, standard busy tone is applied. When the called number is that of a P.B.X. group, the selector automatically searches for a free line in the group, returning busy tone only when all lines are engaged.

A caller dials "0" to obtain access to the parent exchange manual board. The circuit is arranged so that, when the digit 0 is dialled, the selector steps to level 9, the surplus impulse being used to set up the correct signalling conditions for routing the call to the manual board (and not the automatic equipment) at the parent exchange. The selector searches over the 9th level to find a free junction to the parent exchange, and transmits the appropriate calling condition over the first free parent exchange junction. If the call originates from a coin-box line, distinctive conditions are applied to the junction so that the call appears on a separate "coin-box" calling lamp. The bank wiring on the first two choices of level 9 is reversed on alternate selectors so that the service is not interrupted by a faulty first choice junction.

If the digit 9 is dialled, the caller is routed over the same common group of parent junctions, but the signalling conditions are such that the call is switched to an incoming selector at the parent exchange. The caller is now able to dial subscribers on the parent exchange, or to obtain access to other exchanges accessible from the selector levels at the parent exchange. On calls to other (non-parent) exchanges, the initial routing digit steps the selector to the appropriate level, and the wipers are automatically rotated over the group of junctions until a free outlet is found or the whole of the group has been tested.

A route discriminating relay set, which also provides for multi-metering, is associated (when required) with each junction relay set at the U.A.X. This relay set, in conjunction with certain common equipment, provides for 1-, 2-, 3-, or 4-unit metering, and connects the appropriate pulses to the meter wire of the calling subscriber. The same relay set connects N.U. tone to the line if the number dialled is a spare code or is barred to the caller. It also provides manual hold conditions on calls to a distant manual board. In exchanges where there is a large number of dialling codes, certain of the codes require the use of a common auxiliary multi-metering relay set. When this auxiliary equipment is in use on one call, busy tone is returned to any other caller who dials a code connected with the auxiliary equipment.

On incoming calls from the parent exchange to the U.A.X., the calling signal causes the linefinder to extend the junction to the selector circuit.

The operator dials the 3-digit subscriber's number and obtains access to the required line in exactly the same way as for a local call. If the line is engaged, the parent exchange operator can gain access to the line for the offering of trunk calls, etc. by the momentary operation of her ringing key. The telephonist now offers the trunk call to the engaged subscriber and, if he agrees to take it, he is requested to clear the line. When the local call is released, a supervisory signal is given to the manual exchange operator, and a second momentary operation of her ringing key causes the U.A.X. selector to apply ringing to the called subscriber's line.

The U.A.X. 12 makes no provision for extending alarm signals to the nearest attended exchange. A test number (usually 299) is, however, provided so that the parent exchange operator can ascertain if there are alarm conditions at the U.A.X. by observing the tone conditions on the test number. If, on dialling the test number, there are no urgent alarms, inverted ringing tone (2·0 sec on, 0·4 sec off, 0·2 sec on, 0·4 sec off) is connected to the test number, but, if fault conditions exist, continuous N.U. tone is received.

General Construction of Units. The U.A.X. 12 is designed for use in unheated buildings and hence, to protect the equipment from the varying atmospheric conditions, all the switching apparatus (including the M.D.F.) is totally enclosed in air-tight units. The units are constructed of a mild steel framework of angle iron, which is enclosed by a cabinet with double walls of sheet steel. An air cavity between the two walls minimizes the effects of external temperature changes. The doors are of similar construction and are clamped into position by means of metal plates and wing nuts, the joints between the units and the doors being lined with a fabric-covered rubber cord to exclude moisture.

A sheet steel bulkhead divides each unit into two compartments. The upper compartment accommodates the various connexion strips, whilst the larger lower compartment contains the automatic switching equipment. Separate doors are provided for the two compartments, so that work can be carried out on the connexion strips without exposing to the atmosphere the automatic equipment in the lower compartment.

The incoming external cables enter through holes cut into a removable false floor to the M.D.F. unit. After installation, the holes are sealed with a special compound. Holes are provided in the upper compartments to permit of cabling between units. In order to keep the units airtight, a wooden gasket is provided between each pair of units, which fits tightly round the edges of abutting cable holes.

The subscribers' line circuits utilize the No. 600 type relay, whilst all other relays are of the 3000 type. The subscribers' meters are of the No. 100 type, and the 2-motion selectors are of the pre-2000 type design. Apart from the use of enamelled wire for all cabling, the apparatus is of standard design with normal protective finishes.

In order to provide for exchanges of varying size, there are three standard units. These units are designated unit No. 12A, unit No. 12B, and unit No. 12C, and are assembled together as required for each individual exchange.

Unit No. 12A. Fig. 403 gives front and rear views of the A type of unit. The overall dimensions are as follows:

Height	6 ft $10\frac{1}{4}$ in.
Depth .	1 ft 9 in.
Width .	2 ft 0 in.

The weight of the unit with equipment is of the order of 550 lb.

The bottom shelf (when seen from the front) accommodates three mounting plates to provide a total of 25 subscribers' line circuits, each of 3 relays. These same plates also contain the relays associated with the allotter and various routine test relays. The shelf immediately above the line relays contains the linefinders and the allotter switch. Uusually, equipment is provided for 3 linefinders with an extra bank for a 4th linefinder should this be required. The subscribers' meters and the traffic meters are mounted immediately above the linefinder shelf, whilst the space above the meters contains a channel type shelf with a capacity for 4 selector circuits. As with the linefinders, it is usual to supply units with 3 selectors, so that a 4th selector can be added only if required.

At the rear of the unit there are 2 channel type relay set shelves, each with a capacity for 4 relay sets. The lower shelf is wired to accommodate the bothway junction relay sets, whilst the upper shelf is reserved for the associated multi-metering relay sets.

The upper compartment of the unit contains the various connexion strips on which the selector and linefinder bank multiples, etc., are terminated.

Unit No. 12B. The B type of unit is arranged on similar lines to the A unit except that it is narrower (1 ft $7\frac{1}{2}$ in. wide as compared with the 2 ft 0 in. wide of the A unit). It contains equipment for 20 subscribers' line circuits, and has a capacity for 2 linefinders and 2 selectors, although

only one link circuit is equipped when the unit is delivered. At the rear of the rack the 2 relay set shelves provide for 2 bothway junctions and the associated multi-metering relay sets. The B type unit is designed as an auxiliary unit to the A type, and must always be used in conjunction with the latter. The approximate weight of the B unit is 450 lb.

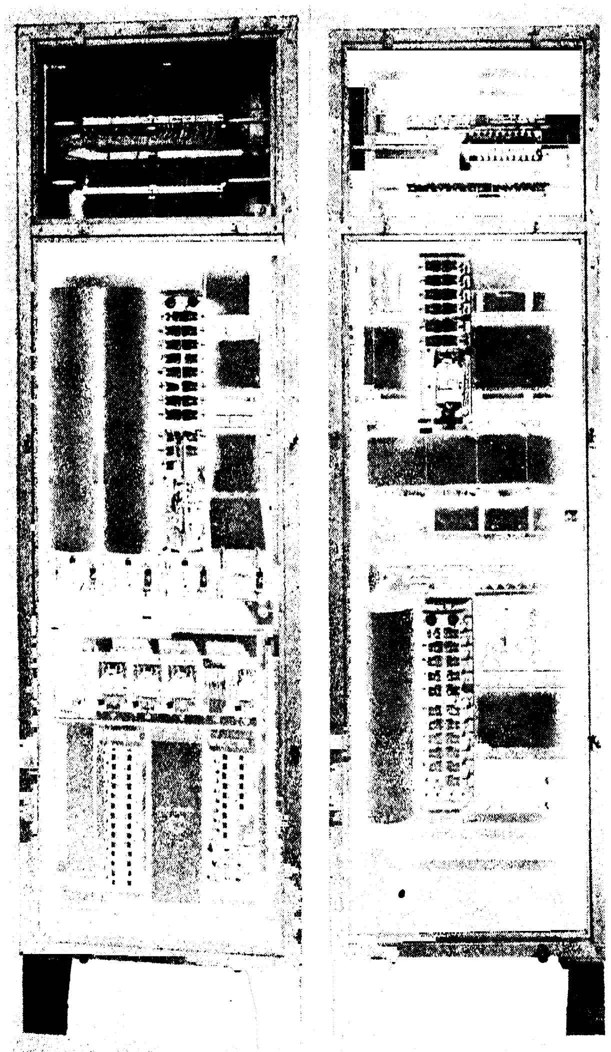


FIG. 403. UNIT NO. 12A

Unit No. 12C. The C unit (Fig. 404) accommodates a small M.D.F. with a capacity for six 20-circuit protectors (at the front) and for 8 fuse mountings (at the rear). (In recent productions, the fuse mountings are fitted closer together than in Fig. 404.) The space above the M.D.F. is utilized for testing equipment (at the front) and for the relay sets associated with the common equipment (at the rear). The ringing current and the various tones are generated by vibrating relays as described later, whilst uniselectors are used for providing the various meter and other pulses. The permanent wiring of the unit is terminated on connexion strips mounted at the top. A telephone (usually connected to No. 290) is mounted on the side of the C unit for use as a

service instrument or for line testing. The C unit has the same external dimensions as the B unit but the weight is somewhat less (300 lb approx.).

Lay-out of Equipment. The No. 12 equipment is designed so that the units can be installed as required to meet the growing requirements of the exchange. The C unit must, of course, be provided at the outset for the termination of the external cables and to provide the various common services of the exchange. The provision of one A unit (in addition to the C unit) provides sufficient equipment for a maximum of 25 subscribers' lines and 4 junctions. If a B unit is now added, the subscribers' equipment is increased to 45 lines, and there is accommodation for 6 junction relay sets. The addition of a second A unit further extends the exchange up to 70 subscribers' lines with a maximum of 10 junctions. Finally, a second B unit provides for the maximum of 90 subscribers' calling equipments and a total of 12 junctions.

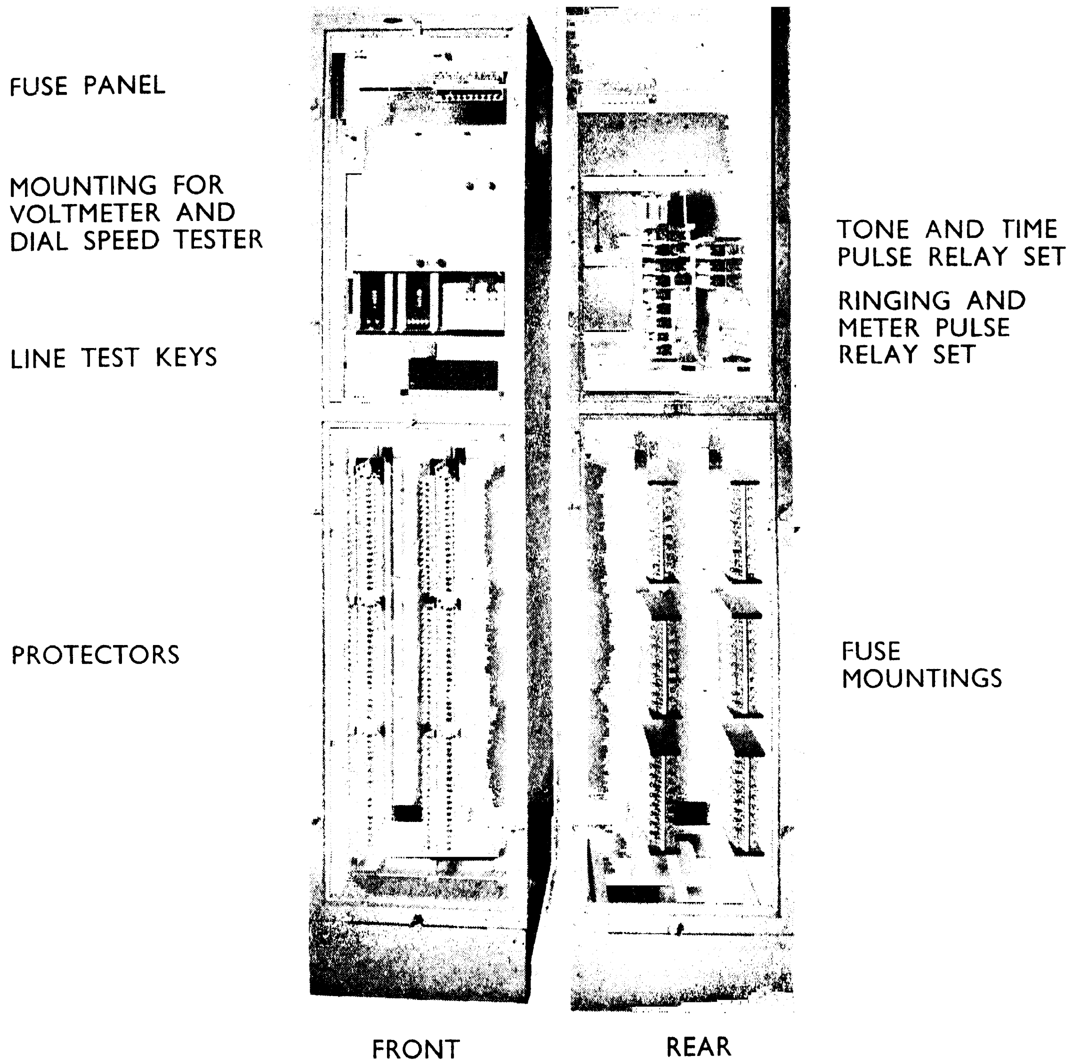


FIG. 404. UNIT NO. 12C

A standard type of building (P.O. type A) with internal dimensions of 14 ft 0 in. × 7 ft 7 in. and a clear height of 8 ft 9 in. is used for all U.A.X.s 12. Fig. 405 shows a typical lay-out of a fully equipped exchange. The 5 units are arranged in a straight line with the front of the units facing the battery

rack. Each unit is steadied by the provision of a tie-bar between the top of the unit and a horizontal angle iron which is firmly fixed to one wall. The external cables enter through a duct below the window, and run in a cable trench which extends below the C unit, a suitable wooden cover being provided for the trench.

The external cables are led through suitable holes in the floor of the C unit and are terminated on the fuse mountings of the M.D.F. Two-wire "jumpers" interconnect the fuse mountings and the protectors. The cables from the protectors leave the C unit through the cable hole near the top and are multipled to terminal strips at the top of each A and B unit throughout the suite. The selector multiple in each unit is also terminated on these same connexion strips. The subscribers' line relays, meters, etc., are cabled to a second set of connexion strips at the top of each unit. By the provision of suitable jumpers between the two groups of connexion strips, any line circuit can be associated with any required multiple number. The linefinder multiple is common for each pair of A and B units to provide a complete 50-line group.

The U.A.X. 12 equipment is designed to work with the standard voltage of 50 V. When an a.c. power supply is available, a single battery automatic float scheme (q.v.) is installed. Where there are no public electric supply mains in the vicinity of the U.A.X. a petrol engine generator set is installed. Fig. 405 shows the lay-out of a U.A.X. 12 with a petrol engine charging scheme. The large water tank for cooling purposes and the petrol tank outside the building will be noted.

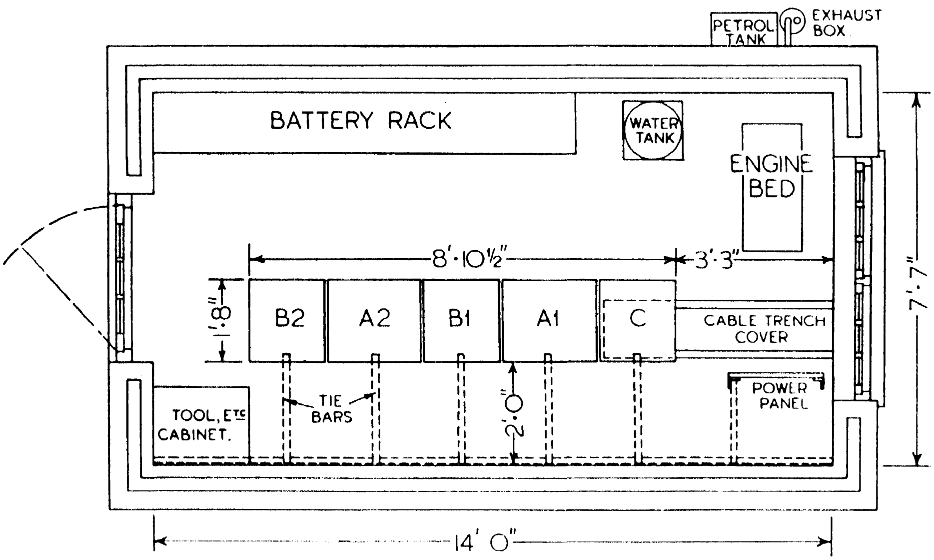


FIG. 405. LAY-OUT OF APPARATUS—U.A.X. 12

Fig. 406 shows a typical U.A.X. 12 building. In this particular case the exchange is faced with red brick, but alternative finishes are available so that the exchange will harmonize as much as possible with the local architecture. All small U.A.X. buildings are provided with cavity walls to exclude dampness and to prevent extreme variations of temperature within the building. Prior to the war it was common practice to line the inside of the U.A.X. with hollow tiles (moler blocks) to increase the heat insulation, but this practice has been largely dropped in recent years due to the difficulty of obtaining suitable materials. The post-war years have also seen new forms of prefabricated structures for U.A.X.s. The shortage of timber at the present time has made it necessary to utilize reinforced concrete roof members, and even reinforced concrete battery racks.

Linefinder and Selector Circuit. Fig. 407 shows the complete link circuit of a U.A.X. 12. Each subscriber's line circuit contains the usual *L* and *K* relays together with a third relay (*P*) which is required to isolate the line under certain fault conditions. The relays for controlling the movements of the linefinder are accommodated on the mounting plate of the 2-motion selector, whilst the four relays of the linefinder allotter circuit are mounted separately along with the subscribers' relays at the bottom of the unit.

The circuit principles follow the usual practice of pre-2000 type selector design, but the appearance of the complete circuit is somewhat complex due to the large range of facilities provided. For purposes of analysis it is desirable to examine the circuit as a number of separate sections. Once these have been examined, the operation of the complete circuit can be readily understood.

Association of Calling Line with Selector. Fig. 408 shows the subscribers' line circuit, the

linefinder, the linefinder allotter, and those parts of the selector circuit concerned in the search for and seizure of a calling line.

When a subscriber lifts his receiver, relay *L* operates to the loop and at **L1** applies a marking battery via *K* and *YA* in parallel to the *PL* bank of the linefinder. The break side of **L1** removes the testing battery from the selector multiple to engage the line to incoming calls. **L2** operates the start relay *ST* in the allotter circuit. (It should be noted that incoming calls from junctions also mark the linefinder bank and operate *ST* in exactly the same manner.) The circuit is arranged so that the allotter is normally standing on a free outlet but, if this condition does not obtain, ***ST*1** completes the drive circuit for the allotter switch to the earth on the common *M*-wire from contacts *KF*6 of all free selectors. If all selectors are engaged, there are no earths on the *M*-lead and the allotter does not therefore hunt until a selector becomes free. In these circumstances, the selector congestion meter operates to the driving magnet battery and locks via its own contact until the *FDdm* springs open. Contact ***ST*3** is inserted to prevent false operation of the congestion meter when the *ST* relay is not operated but all selectors are engaged.

***ST*2** prepares the circuit of relay *DK*, and, when a free selector is found, *DK* operates from the battery at *YE* via the vertical marking wipers (normal), *KF*5, the *FD*1 arc, to the common earth at *KF*6. **DK1** cuts the allotter drive circuit and operates the relief relay *DR*. ***DR*1** now completes the drive circuit (via arc *FD*2) for the linefinder associated with the seized selector. ***DR*2** pre-operates the selector *A* relay in advance of the linefinder extending the subscriber's loop. The pre-operation is provided to ensure that the relays dependent upon *A* (i.e. *B* and *BA*) are fully fluxed before the first impulse is received. This is particularly important with a slow hunting uniselector linefinder. ***DR*3** applies the linefinder testing relay *FK* to the *PL* wiper. The *DR*4 contact is inserted to prevent the irregular operation of *FK* during allotter search over busy outlets. Similarly, ***DR*6** prevents incorrect operation of the congestion meter when *ST*3 restores and before ***DK*1** releases. ***DR*5** energizes the allotter magnet in readiness for stepping when switching is complete.

The linefinder rotates in search of the marking battery of the calling line, and, when this is found, relay *FK* operates on its 11 Ω coil. ***FK*1** cuts the linefinder drive circuit and provides a holding earth for the *FK* relay. ***FK*1** also extends an earth via arc *FD*4 to energize *KF* in the selector circuit. ***KF*1** and ***KF*2** extend the calling loop to the selector *A* relay whilst ***KF*4** provides a holding circuit for the *KF* relay to the earth at ***BA*6**. ***KF*5** busies the selector to the allotter by removing the marking battery (*YE*) and by connecting the *D*-wire to the *M* common earth. ***KF*6** removes the selector earth from the allotter *M* common and at the same time provides an alternative earth to the *PL* wiper.

Relay *K* in the subscriber's line circuit now operates to the earth at *FK* and later holds to the

FIG. 406. TYPICAL U.A.X. 12 BUILDING

replacing earth at ***KF*6**. ***K*1** and ***K*3** remove the *L* relay and earth from the lines whilst ***K*2** disconnects the low resistance marking battery and provides a hold circuit for *K* independent of **L1**. After a release lag, *L* restores to allow relays *ST*, *DK*, *DR*, and *FK* in the allotter circuit to release. The allotter magnet is stepped on the release of *DR*5 and *FK*2 and the switch drives via its own interrupter contacts until no earth is encountered on the *FD*1 arc, i.e. until the first free selector is found. The allotter circuit is now free for use on another call. When the calling subscriber clears, relays *A*, *B*, *BA*, and *KF* release in turn to restore the normal conditions.

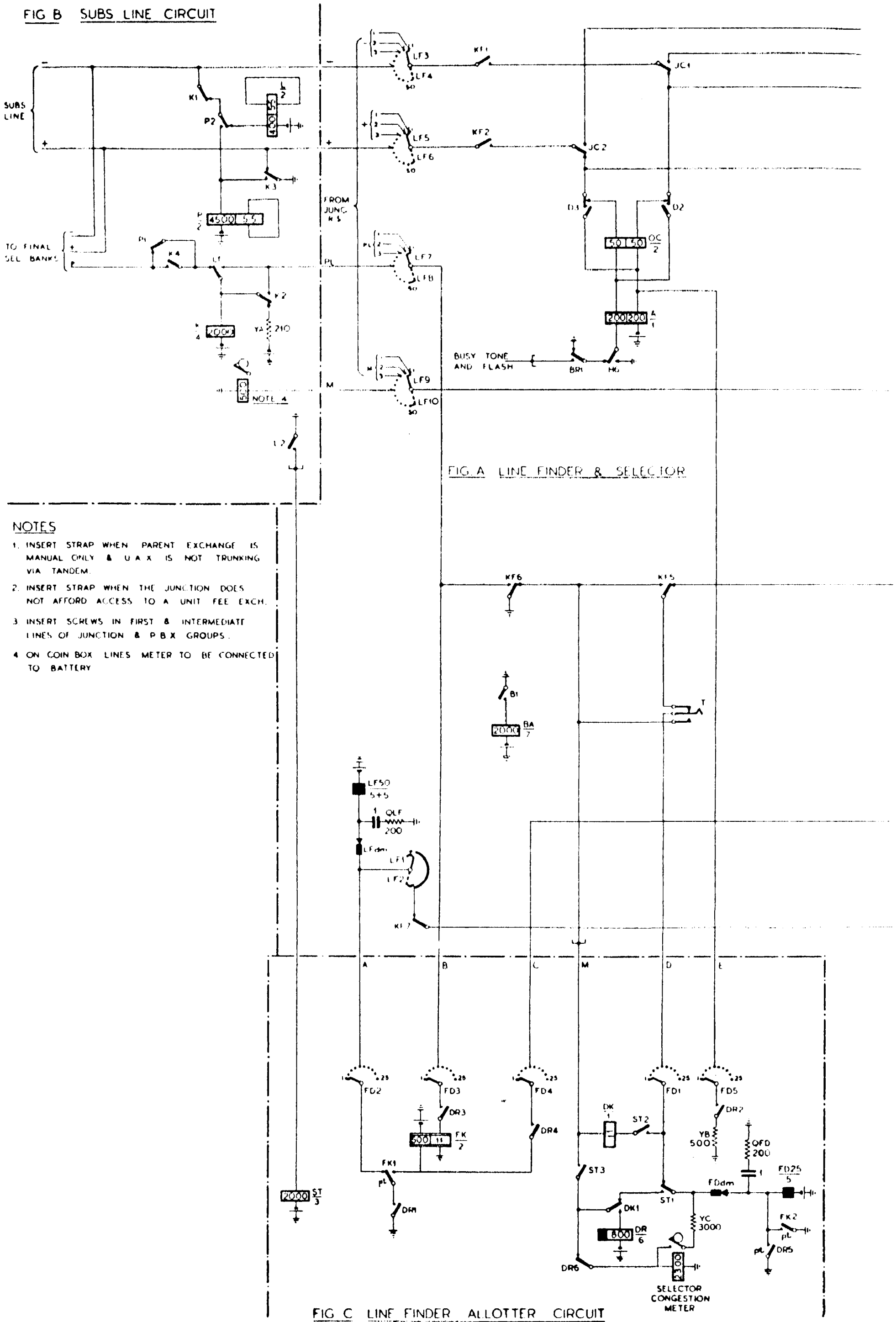
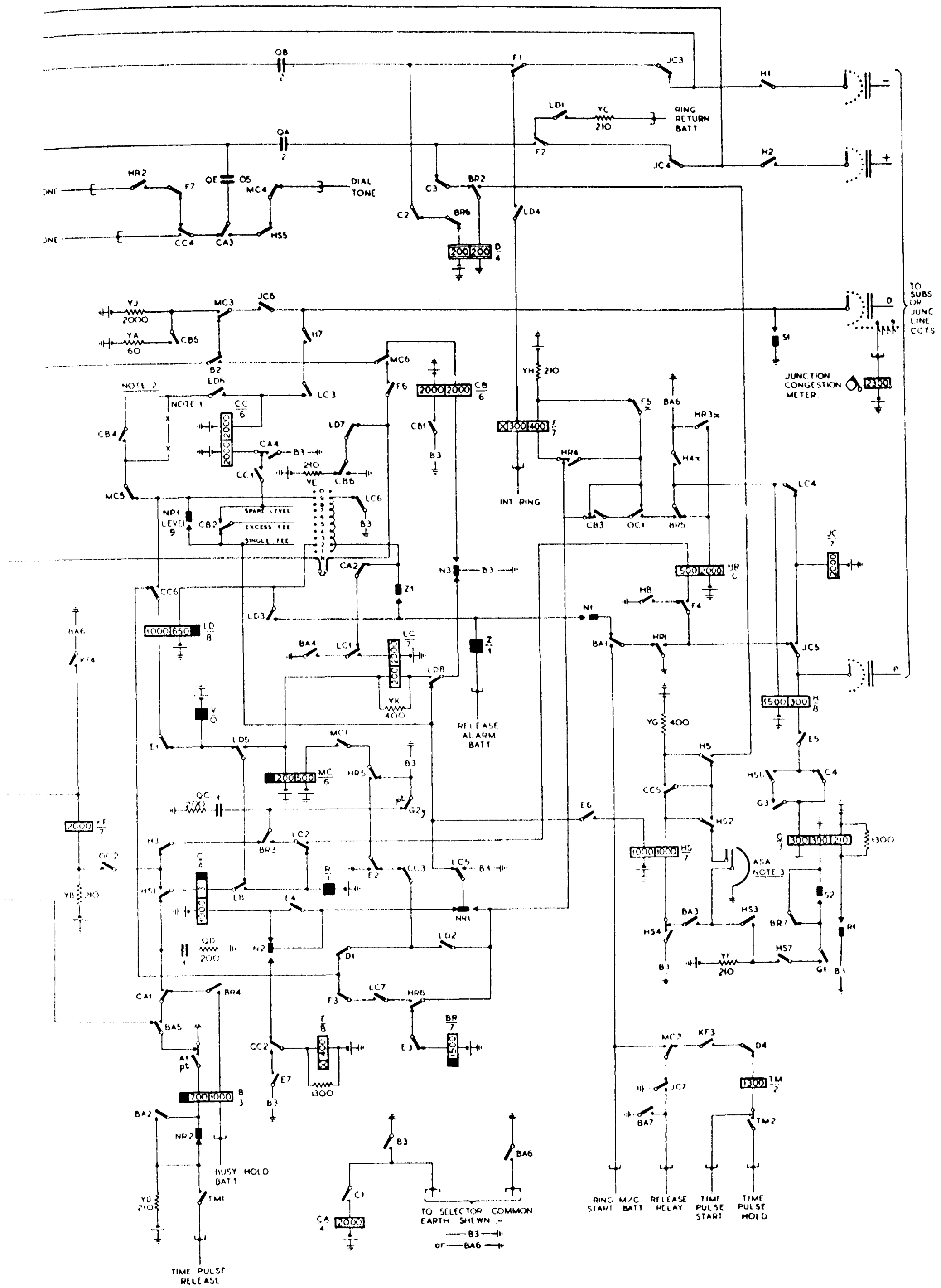


Fig. 407. Complete Linefin



AND SELECTOR CIRCUIT

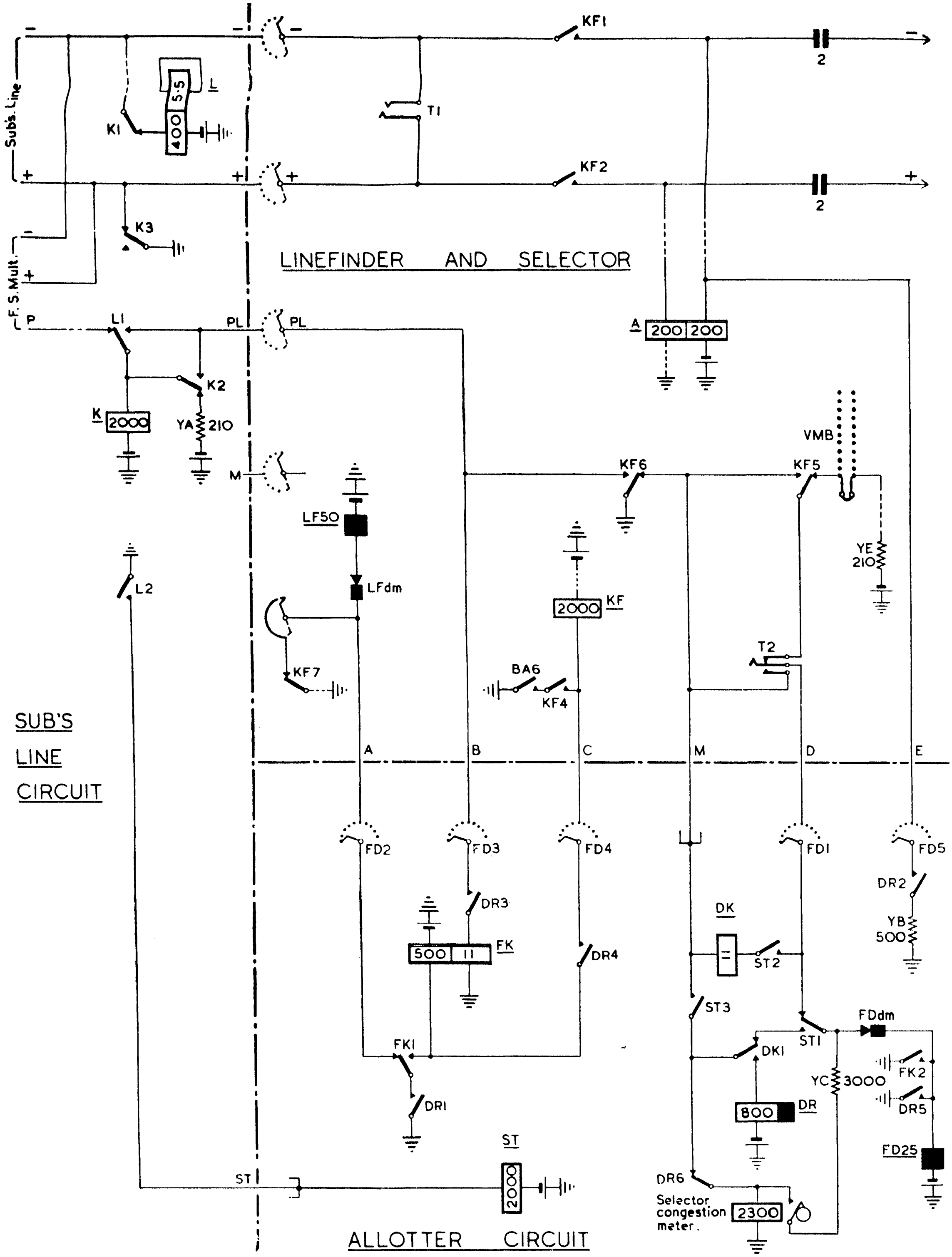


FIG. 408. SUBSCRIBER'S LINE RELAYS, LINEFINDER AND ALLOTTER CIRCUIT

A faulty switch may be busied to the allotter by the operation of test springs *T*2 which simulate the operation of contact ***KF*5**. It should be noted, however, that, if all the remaining selectors are engaged, the allotter will continue to search for so long as a start signal persists due to the earth at *KF*6 of the faulty switch.

Local Call Discrimination. It has already been stated that the first digit (always 2) of a local number is absorbed by the selector in order to provide a local discriminating signal. The circuit element by means of which this discrimination is effected is shown in Fig. 409. On receipt of the initial digit 2, the switch steps to the second level, and in the interdigital pause relay *CA* releases (see later). *CA*2 completes a circuit for relay *LD* from the earth at *LC*1 via the vertical marking bank and wipers. ***LD*3** energizes the release magnet *Z*, and both *LD* and *Z* are held via the ***Z*1** contacts during release of the switch. When the wiper shaft restores to normal, springs *N*3 close and provide an operate circuit for relays *LC* and *MC* in series. These two relays are held at ***LC*1** and ***MC*1** respectively, and *LD* and *Z* are now released by ***LC*1**. The remaining contacts of *LC* and *MC* are used, as will be seen later, to provide the required "local discrimination" conditions in the rest of the selector circuit.

Local Call from Ordinary Subscriber. Fig. 410 shows the portions of the selector circuit required on a local call from an ordinary subscriber. Relay *A* is operated first by the allotter and then by the extension of the subscriber's loop.

The following sequence of operations now takes place:

***A*1** operates relay *B*.
***B*1** operates relay *BA*.
***B*3** operates relay *C*.
***C*1** operates relay *CA*.
***CA*4** operates relay *CC*.

The impulsing circuit is now fully prepared at ***BA*5** and ***CA*1**, and the *D* relay is disconnected from the — and + lines to prevent distortion of the impulses. Dial tone is connected to the caller at ***CA*3**. The *A* relay responds to the initial digit 2 and steps the switch vertically. The pre-operate circuit of *C* is broken at the first vertical step by ***N*2** and the relay is held during stepping on its 3 Ω coil. *C* releases at the end of stepping and is followed by the release of *CA* and *CC*. *CA*3 disconnects the dial tone and *CA*2 allows the operation of *LD* via the vertical marking bank. The selector is released as previously explained and relays *LC* and *MC* are operated and held. ***LC*5** re-establishes the pre-operate circuit of *C* when the wiper shaft is normal and relays *CA* and *CC* are again operated in sequence.

The selector is now ready to receive the second impulse train which steps the switch vertically. *C* again releases at the end of the impulse train and is followed by the release of *CA* and *CC*. The restoration of *CC*2 allows *E* to operate via ***N*2**, *NR*1, and ***LC*5** to the earth at ***B*3**. ***E*8** changes over the impulsing circuit to the rotary magnet (*R*) and at ***E*4** again pre-operates *C* in readiness for the last digit. The relief relays *CA* and *CC* are operated as before.

The *A* relay responds to the third and final train of impulses which is routed to the rotary magnet.

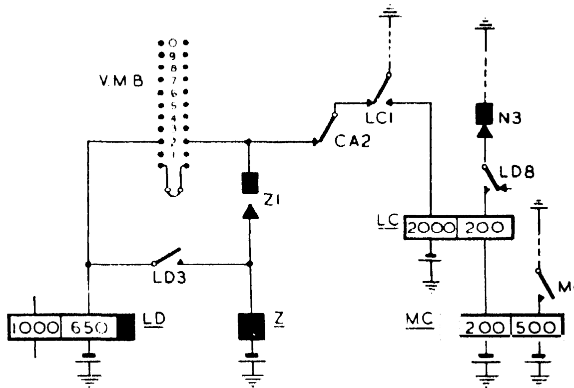


FIG. 409. CIRCUIT ELEMENT FOR LOCAL DISCRIMINATION

At the end of the train, relays *C*, *CA*, and *CC* release. On the restoration of *CC*2, relay *E* commences to release, and during its release lag applies (at ***E*5**) the *H* relay to the *P* wiper of the selector.

If the required line is disengaged, *H* operates to the 210 Ω battery in the line circuit and seizes the circuit by the application of a guarding earth at ***H*8**. The subscriber's *K* relay is now operated and the *L* relay is removed from the speaking pair (Fig. 408). The *H* relay is held on its second winding by ***H*4*x*** and the relief relay *HR* is operated over this same circuit. ***H*1** and ***H*2** switch the — and + lines, and ***HR*2** connects ringing tone to the caller. ***HR*5** transfers the holding circuit of *MC* first to contact ***E*2**, then to ***LD*2** when *E* fully releases. When *E* releases, *LD* is again operated (by *E*1) over the circuit just completed by ***HR*6**. ***LD*1** and ***LD*4** connect ringing current to the called subscriber.

When the subscriber answers, relay *F* operates and locks at ***F*5*x*** by the removal of the short

circuit from the 400 Ω winding. ***F7*** disconnects *ringing tone.* ***F3*** *disconnects the operate circuit* of *LD* which now holds via ***LD2*** under the control of *D*1. Relay *D* now operates to the called subscriber's loop and at ***D2*** and ***D3*** reverses the connexions of the *A* relay to give supervision. ***D1*** disconnects the *LD* relay which applies metering battery at *LD*7 to the calling subscriber's meter. *LD*2 disconnects the holding circuit of *MC* which releases after a lag period to disconnect the meter pulse at *MC*6.

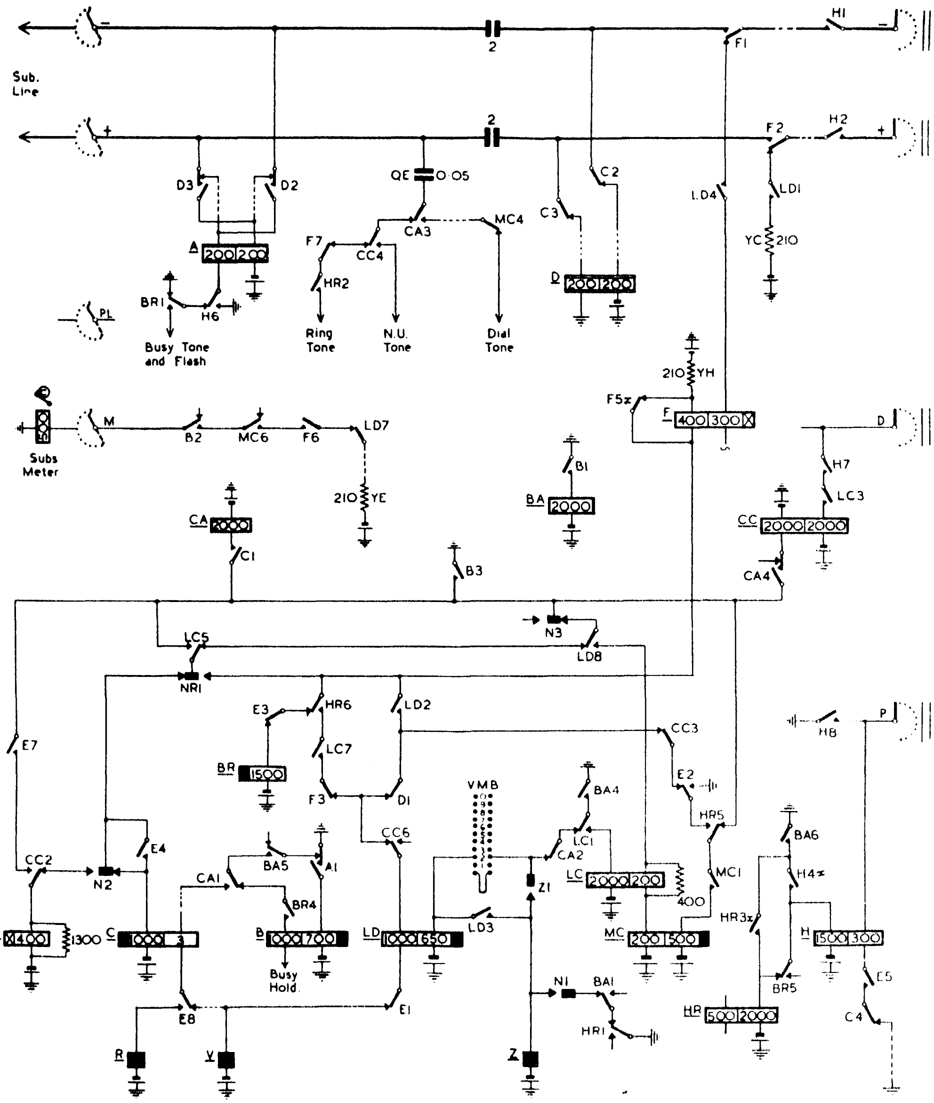


FIG. 410. PORTION OF SELECTOR CIRCUIT CONCERNED WITH A LOCAL CALL FROM AN ORDINARY SUBSCRIBER

If the called subscriber is engaged, the presence of earth on the *P*-wire prevents the operation of *H* during the release lag of *E*. Since *HR*6 is now normal, relay *BR* operates on the release of *E*3. ***BR*1** connects busy tone and flash to the caller and ***BR*4** completes the busy hold circuit of relay *B*.

It is possible, by dialling an incorrect number, for a subscriber to step the wipers to a bank contact occupied by a junction. For example, if there is a junction on the first contact of the 9th level, it is

possible to step the wipers to this position by dialling 291. In these circumstances, relay *CC* is re-energized on the operation of ***H7*** from an earth in the junction relay set via the *D* wiper. ***CC*4** returns N.U. tone to the caller, and ***CC*6** prevents the re-operation of *LD*, whilst ***CC*3** breaks the hold circuit for *MC*. The lines are therefore disconnected at *F*1, *F*2, and at *LD*1, *LD*4.

Automatic Rotary Hunting. Automatic rotary search is provided in order that all lines of a P.B.X. group or all junctions of a group may be tested before busy tone is returned to the caller. The auxiliary arc (*ASA*) has screws inserted in all except the last line of each P.B.X. or junction group (Fig. 411). When the wipers are stepped to the first line of a group by dialled impulses, there is therefore an earth standing on the leading wiper of the *ASA* arc. Relay *HS* operates from this earth via ***BA*3**, *HS*4, *CC*5, and *H*5 to the battery at *YG*. ***HS*2** and ***HS*4** provide a holding circuit for *HS* independent of the *ASA* arc and contact *CC*5. ***HS*1** disconnects the normal impulsing circuit and energizes the *R* magnet from the earth at *B*3 via the *G*2 contact. Relay *C* (and its reliefs *CA* and *CC*) are also held over this circuit. The ***R*1** springs now close and operate *G* over the 210 Ω winding. ***G*3** completes the testing circuit to the *P* wiper and ***G*2** breaks the rotary magnet circuit.

If the first line is engaged, there is no holding circuit for *G* to the *P*-wire and the relay releases. *G*2 again steps the *R* magnet and the cycle is repeated until either a free line is found or the last line of the group is reached.

If there is a free line, relay *G* holds to the battery from the subscriber's *K* relay. The rotary search is temporarily held at **G2** whilst *H* operates. ***H*3** then prevents any further stepping whilst ***H*5** disconnects the circuit of *HS*. The operation of ***H*8** releases *G*. The remaining contacts of *H* complete the switching. After the lag period relay *C* releases and in turn allows *CA*, *CC*, and *E* to restore.

When the wipers are stepped to the last line of a group, the absence of earth on the leading wiper of the *ASA* arc allows relay *G* to hold on its centre winding. If this line is engaged, therefore, *G* cannot release when the *R*1 springs open. In due course *C*, *CA*, *CC*, and *E* release and the restoration of *E*3 (Fig. 410) allows *BR* to operate. ***BR*3** cuts the rotary drive circuit via *C* whilst ***BR*7** releases *G*. The remaining contacts of *BR* return busy tone to the caller as previously described.

If the call is a local one to a P.B.X. number, the wipers remain on the last line until the switch is released by the caller. If, however, the call is to a junction group, the local discriminating relay *LC* will not be operated. In this case, a new circuit for the rotary magnet is provided via ***BR*3** and

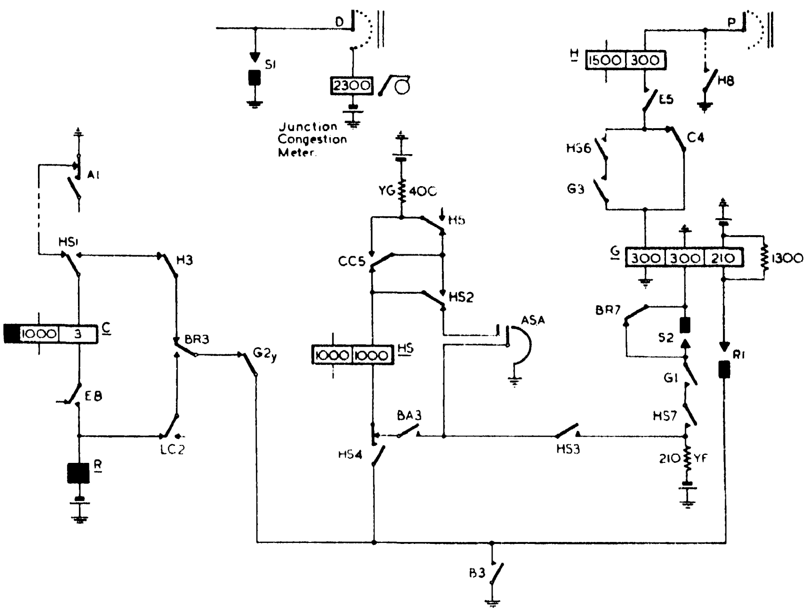


FIG. 411. METHOD OF OBTAINING AUTOMATIC ROTARY HUNTING OVER A GROUP OF OUTLETS ON A SELECTED LEVEL

*LC*2. The *R*1 springs and the *G*2 contact interact as before to drive the wipers to the 11th rotary step. It should be noted that, during this drive, the testing circuit is broken at *E*5 and busy tone is being transmitted to the caller. This is necessary to enable subscribers' lines to be accommodated on the same level. When the 11th step is reached, the *S* springs operate. ***S*2** holds *G* on its centre winding to prevent further stepping whilst ***S*1** operates the junction congestion meter. The selector is then held until the calling party releases.

The rotary hunting circuit provides for night service to any particular intermediate line of a P.B.X. group. If such a number is dialled, relay *HS* cannot operate due to the earth condition on both wipers of the *ASA* arc. The selector will therefore either switch or return busy tone but will not search over the remaining lines of the group.

Junction Call Discrimination. Outgoing junctions to the parent exchange are connected to level 9 but outgoing junctions to other exchanges may be located on any position of the selector bank with the exception of levels 1, 2, and 0. (Level 2, since it is the local discriminating level, must always be reserved for the subscribers' lines numbered 221–220.) When a junction code is dialled, the switch steps vertically but relay *LD* does not operate. On junction calls, therefore, relays *LC* and *MC* are not operated. At the end of the vertical train, relays *C*, *CA*, and *CC* release as usual, and on the restoration of *CC*2 relay *E* operates to an earth supplied via *LC*6 to all working levels of the vertical marking bank (Fig. 412). (It will be remembered that on local calls *E* operates to an earth via ***LC*5**.) ***E*6** now extends the earth from the V.M.B. to operate the *HS* relay.

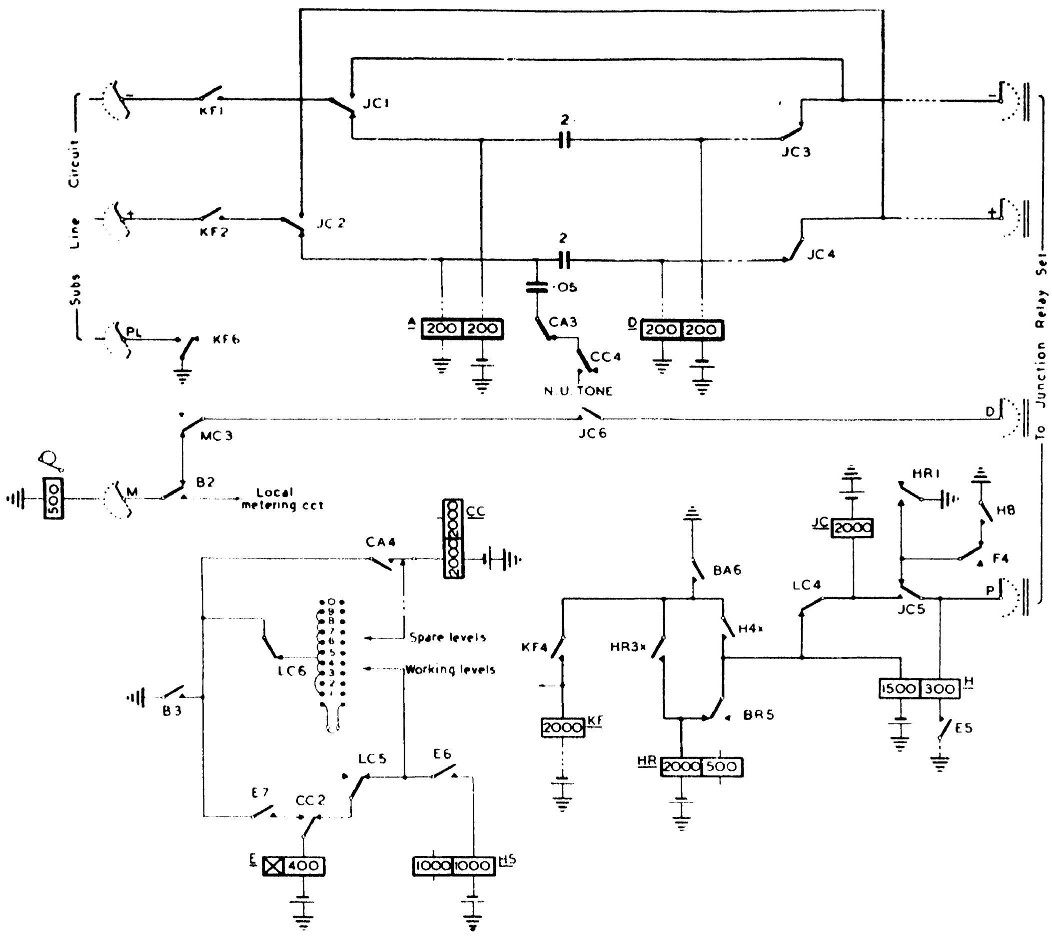


FIG. 412. ELEMENTS FOR DISCRIMINATION AND SWITCHING ON JUNCTION CALLS

Thus, rotary search commences without the necessity of a second digit provided that the junction group occupies the first outlet of the level.

The rotary hunting is exactly as described previously, and in due course relay *H* switches to a free junction. *HR* is operated by ***H*4**, and, since contact *LC*4 is now normal, the ***BA*6** earth is extended to operate *JC*. Contacts ***JC*1**, ***JC*2**, ***JC*3**, and ***JC*4** cut out the transmission bridge, ringing circuit, etc., and extend the speaking conductors to the junction relay set. ***JC*5** extends the *P*-wire to the temporary earth at ***BA*6**. After the lag period, relays *B* and *BA* release (Fig. 410), and for the rest of the call relays *H*, *HR*, *JC*, and *KF* are held by an earth returned on the *P*-wire from the junction relay set. The release of *B* also extends the calling subscriber's meter at *B*2 via *MC*3 and ***JC*6** to the *D*-wire of

the junction relay set, so that in due course the appropriate meter pulses can be applied.

Spare levels are connected to the make-before-break $CA4$ contact. If therefore a subscriber dials a spare level, relays C and CA release at the end of the vertical train but CC is held from the earth via $LC6$ and the V.M.B. There is no circuit for relay E so that rotary search is not started but N.U. tone is returned to the caller at **CC4**.

Parent Exchange Calls. The parent exchange of a U.A.X. 12 is, of course, the manual exchange through which all long-distance calls are passed. It often happens that the parent exchange is an automanual board with an associated automatic system which is within the multi-metering range of the U.A.X. In these circumstances it is more economical to provide a common group of junctions for both the manual board traffic and for calls to the parent automatic area. This, in turn, necessitates some form of differentiating signal from the selector to the outgoing junction relay set. On calls from ordinary subscribers to the parent *automatic* equipment, the 500 Ω earth from the subscriber's meter is extended over the D-wire as on calls to adjacent automatic exchanges. (On calls from C.C.B. subscribers the signal is a 500 Ω battery.) If the call is destined for the parent manual board, this 500 Ω earth or battery signal is replaced by a 2000 Ω battery condition for ordinary subscribers and by a 60 Ω battery on calls from C.C.B. subscribers. Moreover, the manual board discriminating signals are passed forward coincident with the extension of the loop, whereas on calls to the automatic equipment the discriminating signal is delayed for a period of some 300 msec (i.e. the release lag of relay B) after the loop is extended to the junction relay set. This time sequence is necessary in order that the junction relay set can differentiate between an "0" level call from an ordinary subscriber (2000 Ω battery) and a "9" level call from a C.C.B. telephone (500 Ω battery).

The circuit arrangements are as shown in Fig. 413. The junctions to the parent exchange are always arranged as the first choice outlets on level 9 of the selector, the "0" level being reserved for local subscribers. If the call is for the parent automatic equipment, the subscriber dials "9" and the selector is stepped to the 9th level. Relay E operates to the earth from the vertical marking bank via the level 9 normal post springs (***NP*1**). Relay HS operates to give automatic rotary hunting and the call proceeds exactly as a call to an adjacent automatic exchange (see Fig. 412).

If the subscriber requires the parent operator, he dials "0." The first 9 impulses step the selector to the 9th level when relay LD operates to the V.M.B. earth. (***CC*6** is operated during the impulse train.) ***LD*5** disconnects the vertical magnet and routes the 10th impulse to operate MC which locks at ***MC*1**. After a lag, relays C, CA, and CC release and $CC2$ allows relay E to operate to the earth via ***NP*1**. E now operates HS and the call proceeds as for a normal junction call except

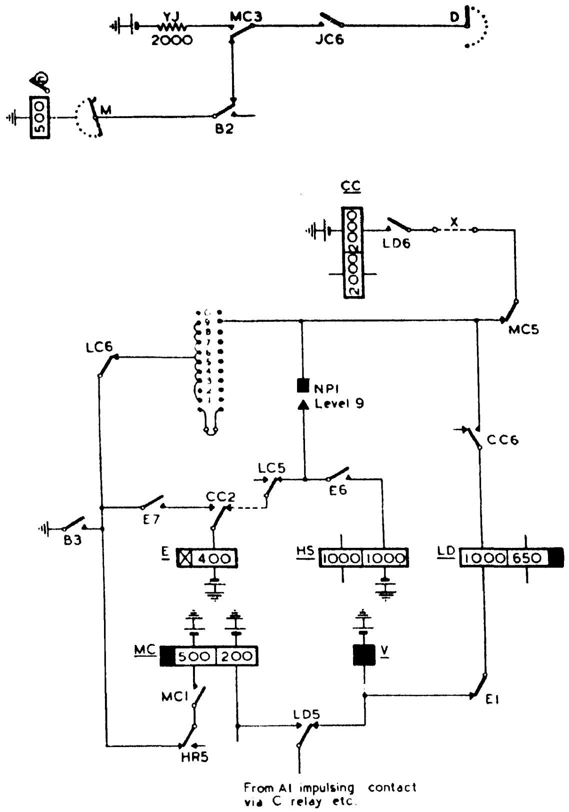


FIG. 413. DISCRIMINATION CIRCUIT FOR PARENT EXCHANGE CALLS

that the 2000 Ω battery at YJ is extended to the outgoing junction relay set by ***MC*3**.

If the parent exchange is manual only, strap X (Fig. 413) is inserted so that, when "9" is dialled, CC is held when C and CA release. This returns N.U. tone to the caller (see Fig. 412).

Coin-box Discrimination. It is necessary to differentiate on calls from telephones with coin-collecting boxes so that

(*a*) the operator at the parent exchange can collect any necessary fee,

(*b*) the subscriber is barred from all junction calls on an automatic basis except those within the unit fee area.

A coin-box discrimination feature (Fig. 414) *is therefore included in the selector circuit. The meters of all coin-box lines are connected to* battery instead of to earth. When the selector is

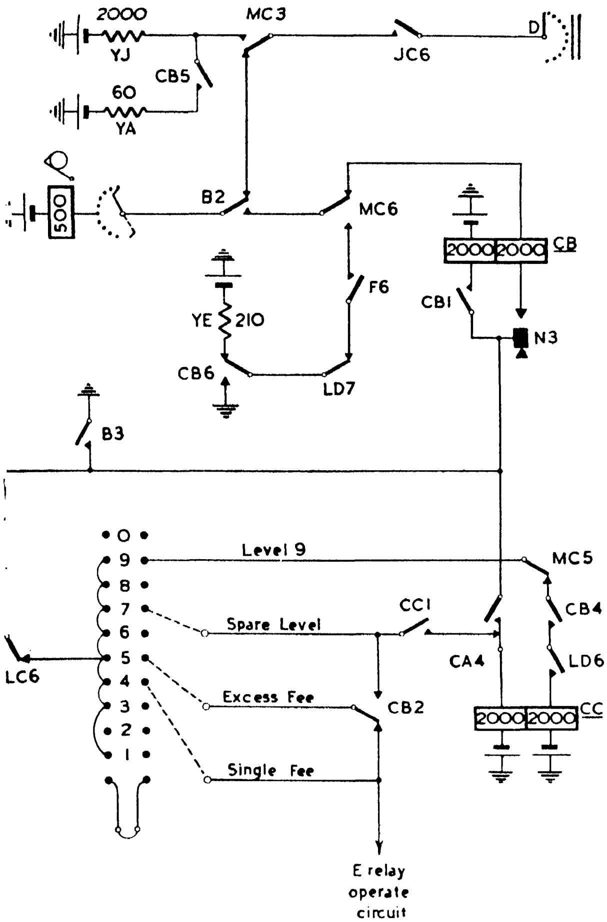


FIG. 414. COIN-BOX DISCRIMINATION ELEMENT

stepped from normal, relay *CB* operates to this battery and locks via ***CB*1** to the earth at ***B*3** for the duration of the call. ***CB*6** corrects for the reversal of the meter connexion by replacing the metering battery at *YE* by a full earth. Similarly, on "0" level calls, ***CB*5** shunts the 2000 Ω battery on the *D*-wire by a 60 Ω battery to give a distinctive discriminating signal to the outgoing junction relay set.

The barring of excess fee junctions is provided by contact ***CB*2**. The "working level" lead of Fig. 412 which provides the operate circuit for relay *E* is, in fact, divided into two leads, "single fee" and "excess fee." Normally, these two leads are commoned by the break contacts of *CB*2, but on coin-box calls all excess fee levels are *changed over to the "spare level" common. If an excess fee level is dialled, relay CC is held on* the release of *CA* and returns N.U. tone to the *caller. Similar conditions exist if the parent* automatic exchange is outside the unit fee area of the U.A.X. In these circumstances, ***CB*4** holds the *CC* relay if "9" is dialled.

Forced Release of Faulty Lines. It is important in a small automatic exchange that faulty lines should not be allowed to seize and hold the few available connecting links. The selector circuit therefore provides for the isolation of a line which has an earth fault on the negative wire. An earth on the negative line operates relay *L* in the line circuit, and a free selector is caused to search for and seize the line. Relay *KF* operates from the allotter circuit (Fig. 415) and at ***KF*6** energizes relay *K* in the line circuit. ***K*2** removes the *L* relay from the line and ***K*3** operates relay *P*. The lines are extended to the selector, but the unbalance of current in the two lines allows the differentially connected *OC* relay to operate. ***OC*2** applies a short circuit to the *KF* relay which in turn releases relay *K* in the line circuit. *K*3 breaks the operate circuit of *P*, but this relay continues to hold via *K*1 and ***P*2** to the earth

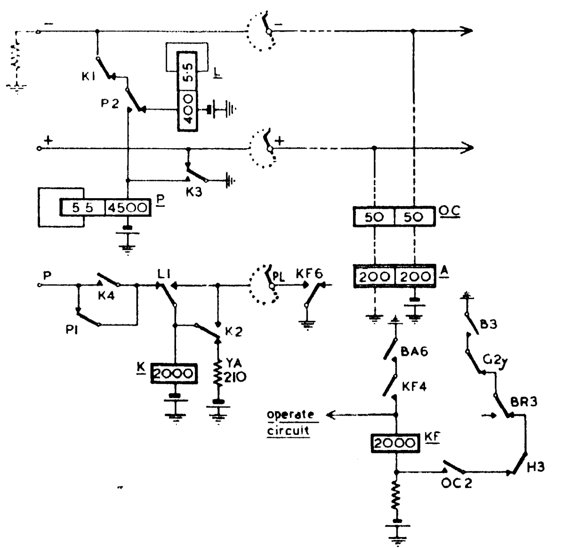


FIG. 415. FORCED RELEASE CIRCUIT

fault. The break side of ***P*2** also prevents the operation of the *L* relay and thereby avoids an allotter start condition. ***P*1** engages the final selector multiple. This lock-out remains until the fault condition is removed. It will be noted that the *P* relay is of very high resistance to minimize

battery drain. Provision is also made (as described later) for the release of the selector and the isolation of the circuit if the lines are looped but the selector is not stepped within a prescribed period.

Trunk Offering. Facilities are provided so that the parent operator can offer an incoming long-distance call to a U.A.X. subscriber who is engaged on a local call. The operator sets up the call in the usual manner and if she encounters Busy Tone only. When the ringing key is thrown, contact ***OC*1** in conjunction with contact ***CB*3** removes the short circuit from the 400 Ω coil of relay *F*. *F*, in operating, extends the — and + lines at ***F*1** and ***F*2** and locks at ***F*5*x***. At the same time, ***OC*1** extends the earth from ***B*3**, via ***LC*5**, ***NR*1**, ***CB*3** and ***BR*5** to operate the *H* relay. ***H*1** and ***H*2** complete the speaking pair to the called subscriber, whilst ***H*5** operates *D* to darken the supervisory

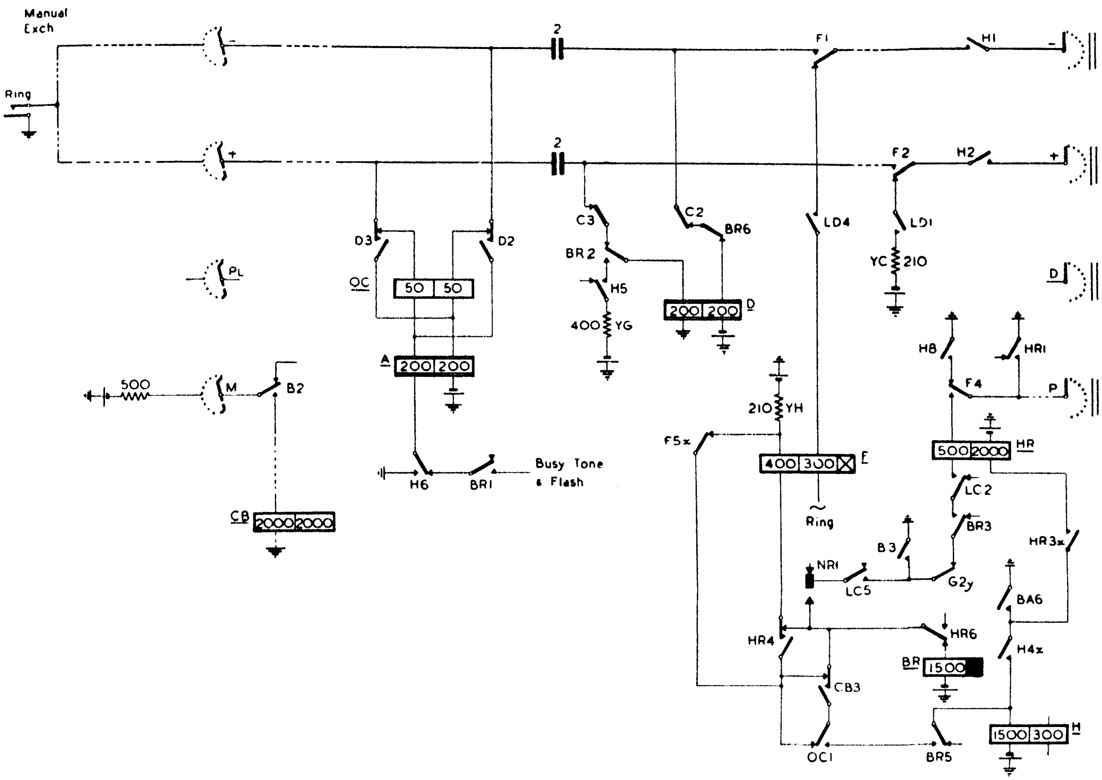


Fig. 416. Circuit Arrangements to Provide Trunk Offering

and Flash she momentarily operates her ringing key. This applies an earth to the junction (Fig. 416) which causes an unbalance of current in the two wires of the loop. Relay *OC* is in series with the *A* relay of the selector but is connected differentially. The normal loop current, therefore, does not affect *OC* until the line currents are unbalanced by the application of an earth at the distant end. Since the trunk offering facility is required only from the parent exchange, the incoming parent junctions are arranged to give coin-box conditions (i.e. 500 Ω battery) on the *M*-wire whereas junctions from other manual exchanges present a disconnexion on the *M*-wire. Thus the *CB* relay is operated on calls incoming from the parent exchange lamp at the manual exchange. ***H*6** disconnects Busy Tone and Flash.

The operator now offers the long-distance call to the subscriber and, if he is willing to accept it, he is instructed to replace his receiver. The release of the local call restores the battery via relay *K* (subscriber's line circuit) to the *P*-wire. Relay *HR* now operates to this battery from earth at ***B*3** via *G*2, ***BR*3** and ***LC*2**. ***HR*1** engages the line and operates *K* in the subscriber's line circuit. ***HR*3** provides a hold circuit for *HR* whilst ***HR*4** transfers the control of *F* to contact *OC*1 (which is now released). ***HR*6** releases *BR* and *BR*2 in turn releases *D*. The restoration of *D*2 and *D*3 now gives a supervisory signal to the manual

operator to indicate that the line has been cleared. The operator proceeds to ring the called party by again operating the ringing key. *OC* operates for the second time and at *OC*1 releases relay *F*. *F*1 and *F*2 apply ringing current to the called line whilst *F*5 prevents the re-operation of *F* until the called party answers.

Junction Signalling. The junction relay sets at a U.A.X. 12 are of a universal type suitable for use on routes to adjacent automatic and manual exchanges in addition to the main route to the parent exchange. Since there are comparatively few junctions in each group, it is usually more economical to work the junctions on a bothway basis, and hence the junction relay set includes all the facilities both for outgoing and for incoming traffic to exchanges of various types. It has been stated that a single group of junctions is invariably provided to the parent exchange and, when the parent centre is automatic, this common group of junctions carries traffic both to the parent exchange manual board and to the automatic network at the parent centre. Provision must also be made on the parent route to give a distinctive signal to the manual exchange operator if a call emanates from a coin-box subscriber.

The circuit of the complete junction relay set is necessarily somewhat complex, and it is preferable to consider its component parts rather than the circuit as a whole. Before doing so, however, it is desirable to summarize the fundamental signalling conditions on the junction for calls of various types. For purposes of analysis the traffic over the junction routes from a U.A.X. may be considered under the following headings:

(1) *Calls from an Ordinary Subscriber to the Parent Exchange Operator* ("0" *Level Calls*). The calling condition is a battery transmitted from the U.A.X. over the + wire of the junction. The answering condition is the return of a battery from the parent exchange over the — wire.

(2) *Calls from a Coin-box Subscriber to the Parent Exchange Operator* ("0" *Level Calls*). The calling condition is an earth transmitted over the — wire of the junction from the U.A.X. The answering condition is an earth over the + wire from the parent exchange.

(3) *Calls from a U.A.X. Subscriber to the Automatic Equipment at the Parent Centre* ("9" *Level Calls*). The seizure signal is a loop from the U.A.X. which is followed by loop-disconnect dialling. The answering condition is a reversal of the line current to the U.A.X.

(4) *Calls to Adjacent Automatic Exchanges.* Same signalling conditions as to parent exchange automatic network.

(5) *Calls to Nearby Manual Exchanges.* Same conditions as on calls to parent exchange manual board.

(6) *Manual Hold.* On calls from ordinary or coin-box subscribers the manual hold condition is a battery returned over the + wire of the junction after the seizure signal is withdrawn from the outgoing end.

(7) *Incoming Calls from C.B., C.B.S. or Magneto Exchanges.* The initial seizure condition is a battery on the + line. Dialling is by loop-disconnect impulsing.

(8) *Calls Incoming from Automatic Exchanges or Sleeve Control Manual Exchanges.* The seizure condition in this case is a loop followed by loop-disconnect impulsing.

(9) *Trunk Offering.* Trunk offering from the parent exchange to a U.A.X. subscriber is obtained by the application of an earthed loop signal from the manual exchange.

Coin-box Discrimination on Junctions. We have seen in the previous paragraph that the junction signalling conditions on calls to the parent exchange operator require the following conditions at the U.A.X.:

Calls from Ordinary Subscriber

Battery to be connected to the + wire for the calling signal.

An earth connected relay on the — wire to receive the battery returned over this wire under the answer condition.

Calls from Coin-box Subscriber

Earth to be connected to the — wire for the calling signal.

A battery connected relay on the + wire to receive the earth over this wire under the answer condition.

With this signalling scheme, it is not possible to apply the supervisory relay at the U.A.X. to the appropriate line until such time as the initial calling signal has been received and recorded by the incoming equipment at the parent exchange: otherwise the supervisory relay circuit would transmit conditions to the junction similar to the alternative calling signal. For example, if on calls from an ordinary subscriber the earth connected supervisory relay were connected to the — wire of the junction during the initial seizure of the circuit, this would imitate the coin-box calling condition (earth on — wire), and it would be impossible for the incoming equipment to differentiate between calls from ordinary and coin-box subscribers.

The difficulty is overcome by arranging a sequence of signals over the junction pair. The supervisory relay is disconnected during the initial seizure signal, but when this seizure signal is received at the parent termination, an acknowledgment signal is returned to the U.A.X. to indicate receipt of the initial calling condition. In order to provide a positive system of control, the acknowledgment signal is maintained until such time as a further signal is received from the U.A.X. to indicate receipt of the acknowledgment. The "acknowledgment received" signal transmitted from the U.A.X. now causes the parent exchange termination to cease the acknowledgment signal and to restore the circuit ready for the transmission of supervisory signals. Finally, the cessation of the acknowledgment signal from the parent exchange is used at the U.A.X. for switching in the supervisory relay.

Fig. 417 shows the basic signalling elements on calls to the parent exchange operator. The upper portion of the diagram (*A*) shows the conditions when the call emanates from an ordinary subscriber. The calling subscriber's loop causes the operation of contact **A2** which extends the battery via *DD* to the + wire of the junction, and then to operate relay *LA* at the manual board termination. Contact **LA1** (diagram *C* of Fig. 417) now lights the calling lamp associated with calls from "ordinary" subscribers. The current over the + wire also operates relay *DD* at the U.A.X., and **DD1** allows relay *DB* to operate and lock. **DB7** now short-circuits the *A2* contact to prevent any irregular dialling by the subscriber from interfering with the junction signalling. (As will be seen shortly, part of the signalling sequence consists of a disconnexion of the + wire, and any release of *A2* would imitate this signal.)

When the operator inserts a plug into the answering jack, relay *SS* is operated, and the changeover of contact **SS4** disconnects the + line to release relays *LA* and *DD*. **SS7** disconnects the calling lamp and **SS3** extends the — wire to relay *CH*. The release of relay *DD* at the U.A.X. now allows relay *J* to operate, and **J2** disconnects the ringing tone and applies a full earth to the — wire of the junction. At the parent exchange, this earth signal is extended through **SS3** and *CH*1 to operate relay *CH*. *CH* in turn re-establishes the + wire circuit by the closure of contact **CH5**. The current in the + line again re-operates relay *DD*, and **DD1** completes a circuit via **J1** to operate relay *JA*. **JA2** withdraws the full earth from the — line and substitutes the earth connected supervisory relay *D*. The circuit is now established for the supervisory signal. The throwing of the telephonist's speak key operates relay *TS*, and **TS1** extends the battery at *LB* via **CH1**

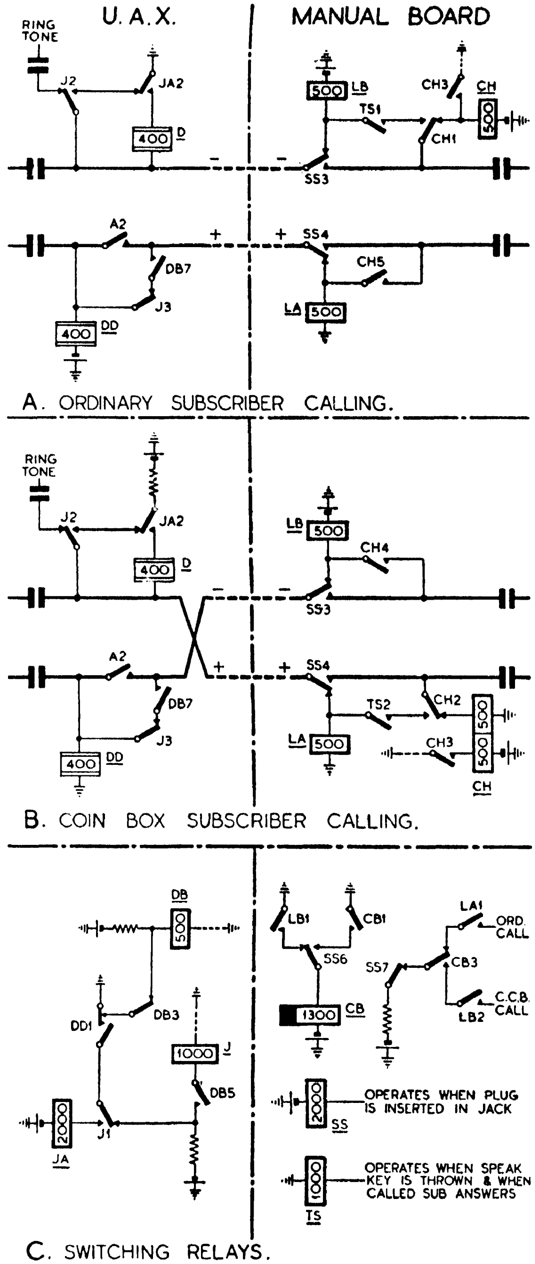


FIG. 417. BASIC SIGNALLING CONDITIONS ON OUTGOING JUNCTIONS FROM U.A.X. 12

and **SS3** to the — wire of the junction and thence to operate relay *D* at the U.A.X.

Diagram *B* of Fig. 417 shows the signalling condition on calls from coin-box subscribers. In

this case the calling signal is an earth via relay *DD* extended over the — wire of the junction to operate relay *LB* at the manual board termination. ***LB*1** operates relay *CB*, and ***CB*3** closes the circuit for the lighting of the coin-box calling lamp. When a plug is inserted in the answering jack, ***SS*7** disconnects the calling lamp whilst ***SS*6** provides a holding circuit for relay *CB* independent of *LB*. The operation of ***SS*3** disconnects the — line current, and the resultant release of relay *DD* allows *J* to operate as before. ***J*2** now extends battery over the + wire of the junction to operate relay *CH* at the manual board. ***CH*4** re-establishes the — line current, and the second operation of relay *DD* energizes relay *JA*. ***JA*2** now disconnects the full battery from the + line and inserts the supervisory relay. When the operator or the called subscriber answers, the operation of ***TS*2** returns earth via ***CH*2** and ***SS*4** to the + line and thence to operate relay *D* at the U.A.X.

Sleeve Control Manual Board Termination. Fig. 419 shows the complete circuit of the relay set, at a sleeve control manual exchange, suitable for the termination of junctions from a U.A.X. Fig. 418 shows elements of the junction relay set at the U.A.X. to indicate the three alternative forms of signalling. In addition to the coin-box discrimination features already described, the sleeve control termination provides for manual hold and for the diversion of the call to an incoming selector should the calling subscriber dial "9."

When an ordinary subscriber dials "0" (or the appropriate code for a non-parent exchange) relays *A* and *BD* of the U.A.X. junction relay set operate. Battery is now sent out on the + line through the coil of relay *DD* and via contacts ***A*2** and ***BD*2** (Fig. 418 (*a*)). At the parent exchange, the battery on the + line operates relay *LA* which, at ***LA*1**, completes a circuit for relay *B*. ***B*1** provides a holding circuit for *B* independent of the earth at *LB*1. ***B*2** energizes the "ordinary subscriber" lamp relay.

When the operator inserts a plug into the answering jack, relays *S* and *SS* operate. ***SS*7** releases the lamp relay, and ***SS*5** provides a hold circuit for *B* independent of ***LA*1**. ***SS*4** disconnects the + wire and thereby releases relay *DD* at the U.A.X. and relay *LA* at the manual termination. The release of *DD* allows relay *J* to operate, and the ringing tone is disconnected at ***J*2**. This contact also applies a full earth to the — line which operates relay *CH* at the manual exchange (via ***SS*3**, ***B*5**, *CB*4, and *CH*1). *CH* locks to ***CH*3** and also breaks the circuit of the slugged *B* relay at ***CH*6**. ***CH*5** re-establishes the + line circuit, and relays *LA* and *DD* re-operate. ***LA*1** provides a holding circuit for *B* before it releases due to the operation of ***CH*6**. *DD* in re-operating energizes relay *JA*, and at ***JA*2** the *D* relay is applied to the — line.

When the operator throws her speak key, relays *DR* and *TS* operate, and battery from relay *LB* is returned via ***TS*1**, ***CH*1**, *CB*4, ***B*5**, and ***SS*3** to the — line and thence to operate relay *D* at the U.A.X. The circuit is now set up for conversation. It will be noted that ***TS*1** returns a supervisory condition to operate relay *D* whenever the called party is on the line.

When a call originates from a coin-box line, discriminating conditions at the U.A.X. reverse the battery and earth connexions to the *D* and *DD* relays, and also reverse the line connexions to these relays (Fig. 418 (*b*)). Earth is now applied to the — line via *DD* to operate relay *LB* at the manual exchange. ***LB*1** operates relay *CB* and ***CB*2** operates *B*. ***B*2** and ***CB*3** energize the lamp relay associated with the coin-box calling lamps. When a plug is inserted in the answering jack, relays *S* and *SS* operate as before and disconnect the — line at ***SS*3**. Relays *DD* and *LB* release, *J* operates, and the resulting battery on the + line energizes relay *CH* via ***CB*5**. ***CH*4** re-establishes the — wire. The resultant re-operation of *DD* energizes relay *JA*, which connects the supervisory relay (*D*) to the + line. When the operator throws her speaking key, the operation of *TS* re-establishes (at ***TS*2**) the + line. Contact *TS*2 is now the controlling contact for the supervisory condition.

Provision is made to hold either an ordinary or a coin-box subscriber when the calling party flashes or clears whilst a call is established at the manual exchange. When the calling party clears, the release of relay *A* allows relays *C* and *CA* to operate, and relays *BD* and *JA* to release. *A*2 disconnects the + line (assuming that the call is from an ordinary subscriber) whilst ***CA*4** disconnects the — line circuit. At the manual exchange the release of relays *LA* and *LB* disconnects the circuit for relay *B*, and after a period of lag the restoration of *B*6 applies battery to the + line to operate relay *MH* at the U.A.X. The contacts of *MH* are arranged to maintain the holding condition throughout the U.A.X. equipment. If and when the subscriber recalls, *CA* releases and at *CA*4 re-applies earth to the — line to operate relay *MH* at the manual exchange. ***MH*1** re-operates *B* and the call is re-established by the subsequent operation of *LA*, *LB*, *D* and *DD*.

We have seen that on parent exchange routes a subscriber can obtain access to the automatic

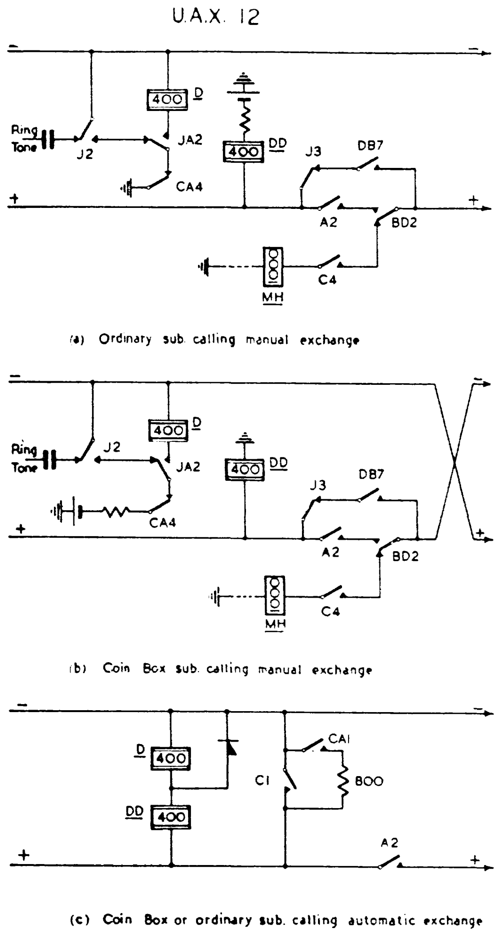


Fig. 418. Signalling Conditions from U.A.X. 12

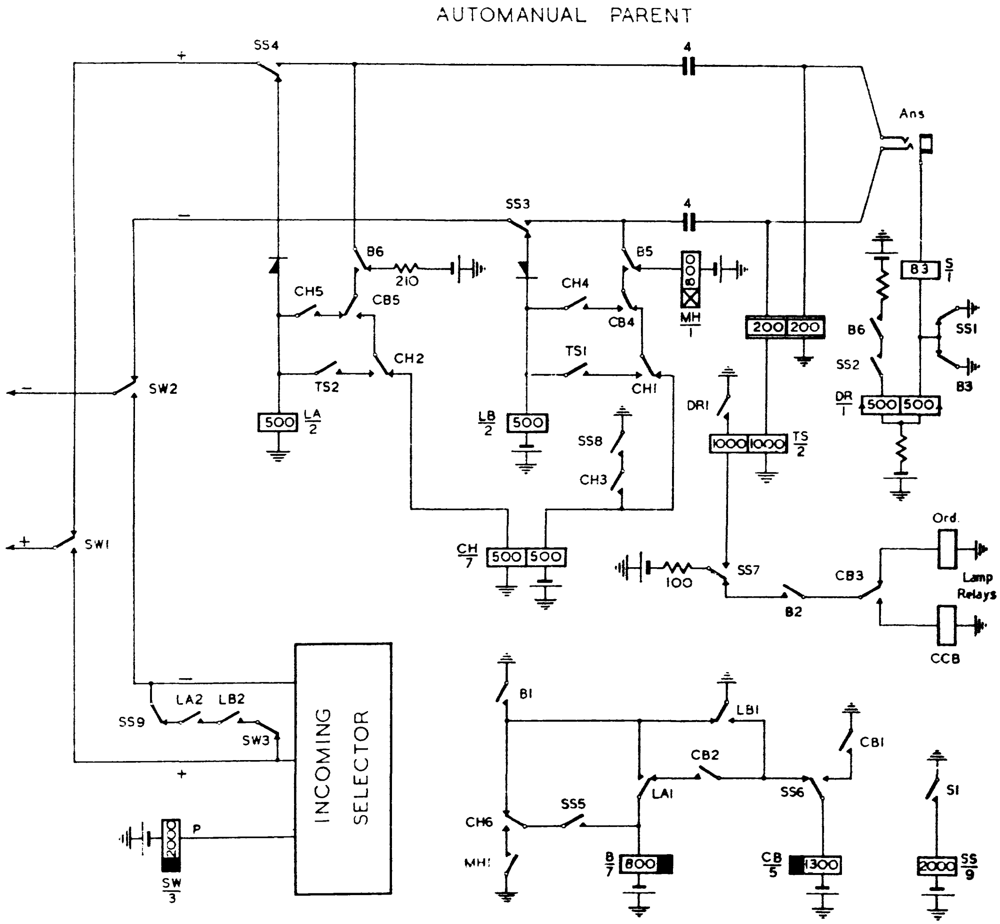


Fig. 419. Termination at Sleeve Control Parent Exchange

equipment at the parent centre by the dialling of a single digit 9. Under these conditions, the seizure signal is a loop from the U.A.X. formed by relays D and DD in series (Fig. 418 (c)). This causes the operation of both relays LA and LB at the junction pair from the manual board termination to the incoming selector, whilst $SW3$ disconnects the temporary seizure loop formed by the LA and LB contacts. Other contacts of the SW relay (not shown in Fig. 419) engage the

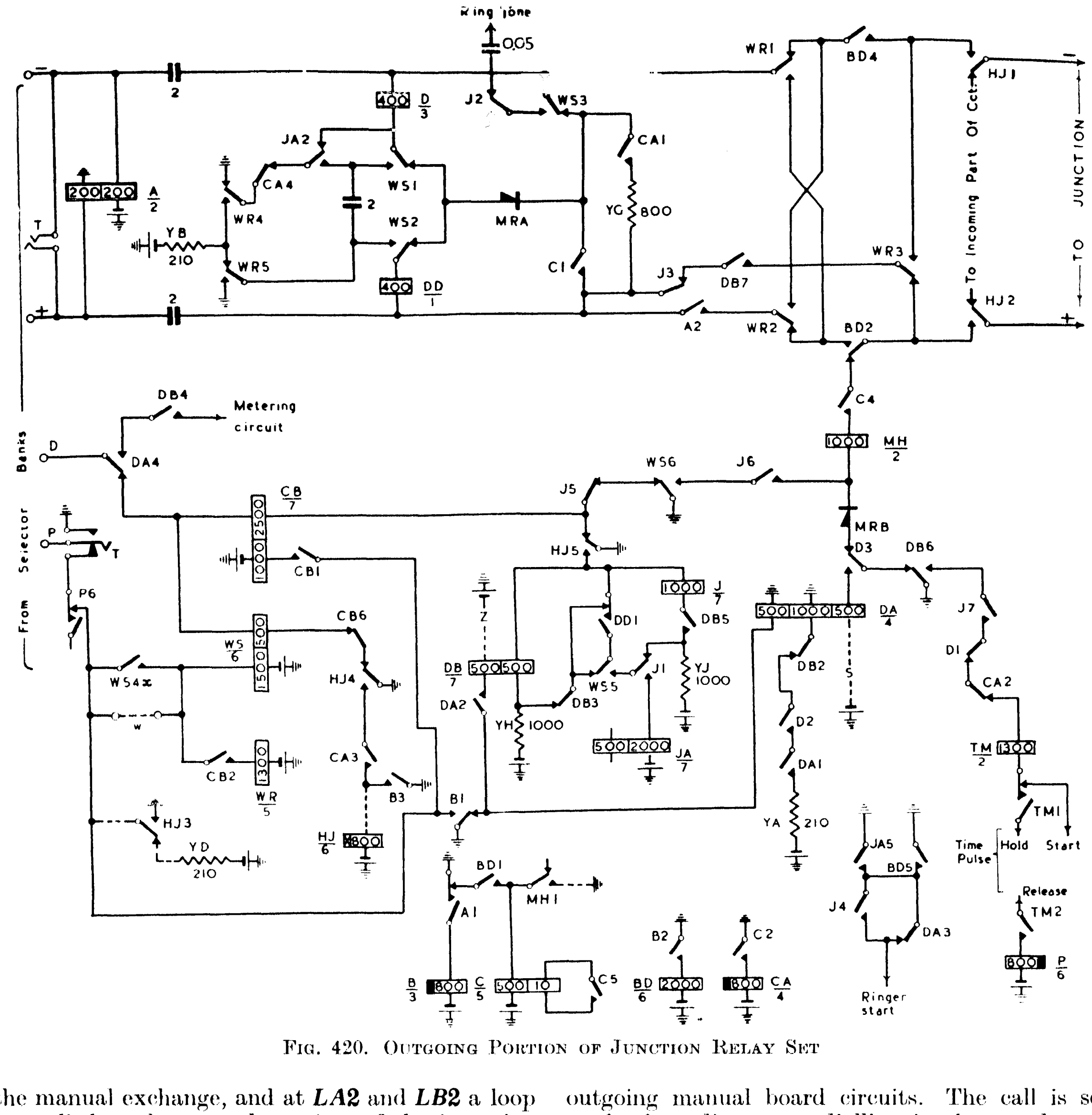


Fig. 420. Outgoing Portion of Junction Relay Set

the manual exchange, and at $LA2$ and $LB2$ a loop is applied to the + and − wires of the incoming selector. (When $LA1$ and $LB1$ are both operated there is no circuit for relay B which provides the calling signal on calls to the manual board.)

The seizure of the incoming selector causes the return of earth on the P-wire which operates relay SW. Contacts $SW1$ and $SW2$ switch over outgoing manual board circuits. The call is set up by loop-disconnect dialling in the usual way, and a two-stage drop-back is provided at the U.A.X. to minimize difficulties due to subsequent pick-up (see Chapter VI). When the called party replies, the reversal of the current in the junction allows relay D at the U.A.X. to operate and to effect metering.

Outgoing Part of Junction Relay Set. Fig. 420 shows in more detail the discriminating and signalling arrangements of the junction relay set. If the junction is free, the 210 Ω battery is applied to the *P*-wire, and the *H* relay of the selector switches to this battery potential as already described. Relay *A* now operates to the extended subscriber's loop and at **A1** energizes the *B* relay. ***B*1** applies a guarding earth to the *P*-wire whilst ***B*2** operates *BD*. ***B*3** completes the circuit for the slow-to-operate *HJ* relay. The appropriate discriminating signal is applied from the selector on the *D*-wire and the marginal relays *WS* and *CB* are operated as follows:

(*a*) On calls from an ordinary subscriber to an adjacent automatic exchange, the 500 Ω earth from the subscriber's meter does not operate either *WS* or *CB*.

(*b*) On calls from an ordinary subscriber to an adjacent (non-parent) manual exchange the *D*-wire conditions are the same as for (*a*) but a strap "*w*" is inserted in the junction relay set to operate *WS* locally when ***B*1** operates.

(*c*) On calls from an ordinary subscriber to the parent manual board, the 2000 Ω battery on the *D*-wire operates *WS* before the circuit is broken at ***HJ*4**. If, however, the call is for the automatic equipment associated with the parent exchange (i.e. "level 9" calls), the conditions are as for (*a*) and *WS* does not operate.

(*d*) On calls from a coin-box subscriber to an adjacent exchange in the unit fee area, the delayed application of the 500 Ω battery from the subscriber's meter operates *CB* but *WS* cannot operate due to the disconnexion of the circuit at ***HJ*4**. When the junction is to a manual exchange relay *CB* operates over the *D*-wire and relay *WS* is operated locally as in (*b*).

(*e*) On calls from a coin-box subscriber to the parent manual board the 60 Ω battery on the *D*-wire operates both *WS* and *CB* (before *HJ* is fully energized). On "level 9" calls *CB* is operated but *WS* is not (as on calls to an adjacent auto-exchange).

To summarize, the following relay combinations are set up:

"0" level calls and calls to adjacent manual exchanges	ordinary subscribers—*WS* C.C.B. subscribers—*WS* and *CB*
"9" level calls and calls to adjacent auto-exchanges	ordinary subscribers—None C.C.B. subscribers—*CB*

After operation, relays *WS* and/or *CB* lock on their second windings to their own contacts (***WS*4** and ***CB*1**) before the initial operating circuits are broken at ***HJ*4** and ***HJ*5**. If both *WS* and *CB* operate, a circuit is provided for *WR* which also operates. Thus, contacts ***WS*1**, ***WS*2**, and ***WS*3** set up "ordinary line" manual calling conditions (Fig. 418 (*a*)), whilst ***WR*1**, ***WR*2**, ***WR*3**, ***WR*4**, and ***WR*5** modify these conditions for coin-box calling (Fig. 418 (*b*)). If neither *WS* nor *WR* is operated, the junction circuit gives loop dialling conditions (Fig. 418 (*c*)).

On calls to a manual exchange, *DB* is energized on the first operation of *DD* and at ***DB*5** prepares the circuit for *J*. *DD* releases when the distant answering plug is inserted and at *DD*1 removes the short circuit from *J*. ***J*2** disconnects ring tone and applies earth to the negative line. In due course the earth is restored at the manual exchange on the positive line, and the re-operation of *DD* energizes *JA* via ***J*1**. The call is now set up for conversation.

Under manual-hold conditions relay *MH* operates to a battery on the positive line and at ***MH*1** holds the *C* relay subsequent to the release of *BD*. *C* in turn holds *CA*, and ***CA*3** maintains the holding relay *HJ*. This condition persists until either the subscriber recalls or the operator withdraws the plug.

On calls to automatic exchanges, facilities are provided to release the selector under called-subscriber-held conditions. If the calling party continues to hold the connexion after the called party has cleared, relays *DB* and *J* are operated and relays *D* and *CA* are released. Relay *TM* now operates over the circuit ***DB*6**, ***J*7**, *D*1, and *CA*2 to battery in the time pulse circuit. ***TM*1** holds *TM*, and after a delay period of several minutes a release pulse is returned to operate *P*. ***P*6** disconnects the private-wire to release the caller from the junction.

The conditions for calls to level 9 or an adjacent automatic exchange are very similar except that relay *DB* does not operate when *DD* is energized (due to the normal position of *WS*5). When the called subscriber answers, ***D*3** prepares the circuit for *DA* and relays *DB* and *J* operate under the control of the metering pulses as described later.

Incoming Junction Calls. Fig. 421 shows the portions of the junction relay set concerned on calls incoming to the U.A.X. If the call is from a C.B., C.B.S. or magneto exchange, the initial calling condition is a battery which operates relay *MH* via the positive wire, *HJ*2, *K*2, *JA*6, etc., to the earth at *DB*6. ***MH*2** completes the negative line circuit to relay *L* which operates from the earth on the negative line applied at the manual exchange. ***L*1** operates *BA*. When the

call originates at an automatic exchange or at a *sleeve control manual exchange, the initial calling* condition is a loop. Under these conditions strap Y is inserted to by-pass $MH2$ by rectifier MRC and thereby to allow relay L to operate directly over the loop in series with MH.

for K independent of ***BA*2**. ***K*4** breaks the JA relay circuit in readiness for the release of L. ***K*6** operates P which at ***P*2** disconnects the linefinder start circuit and at ***P*3** releases relay BA. ***P*6** maintains the engaging disconnexion on the P-wire in readiness for the release of BA. Relays L,

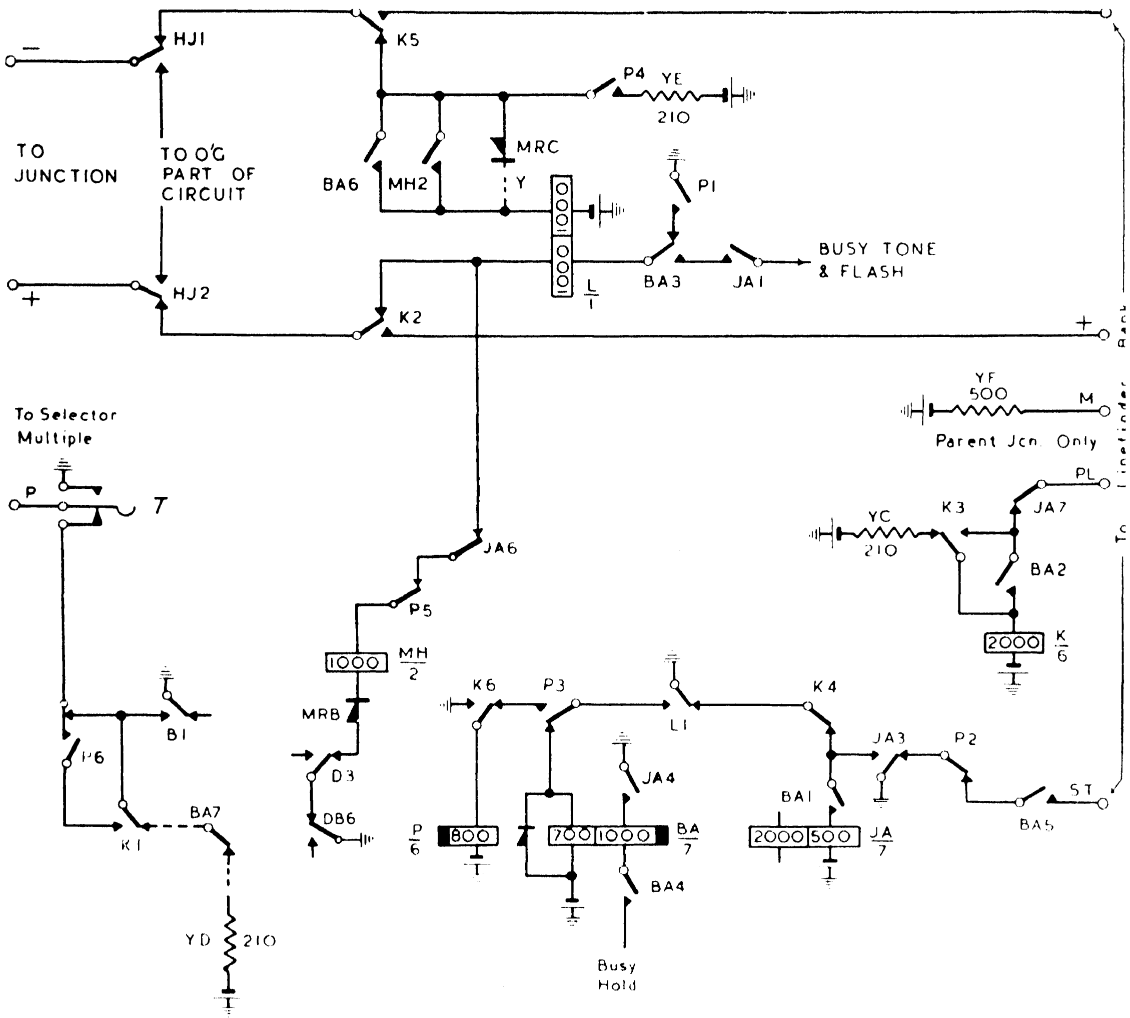


FIG. 421. INCOMING PORTION OF JUNCTION RELAY SET

Relay BA in operating completes the marking circuit to the linefinder banks at ***BA*2**. At the same time ***BA*7** engages the junction to the selector multiple by disconnecting the testing battery on the P-wire. ***BA*5** applies earth to the linefinder start circuit. When the junction is switched to a free selector, relay K operates and at ***K*2**, ***K*5** disconnects relays MH and L and extends the junction to the selector A relay. ***K*3** disconnects the marking battery and provides a hold circuit

BA, and MH are now normal and the call is switched to and held from the selector circuit.

Owing to the time required for the hunting of the linefinder, there is a possibility of dialling commencing before linefinder search is complete and before K is operated. In these circumstances, relay L responds to the dialled impulses and at $L1$ operates JA via $K4$ and ***BA*1**. ***JA*1** returns busy tone and flash to the caller whilst ***JA*4** completes the busy hold circuit for BA.

JA3 disconnects the linefinder start circuit and holds the *JA* relay independent of ***L1***. ***JA7*** disconnects the marking battery from the L.F. bank. This condition persists until the call is released.

If called-subscriber-held conditions persist on an incoming junction call, the selector is released after a delay period and the holding circuit for relay *K* in the junction relay set is broken. *K2* and *K5* apply the *L* relay to the holding loop on the junction, and ***P1*** completes the circuit for *L*. At the same time ***P5*** prevents the operation of *MH*. The junction is thus guarded at ***P6*** until the calling loop is broken. Contact ***P4*** is necessary on calls from C.B., C.B.S., and magneto exchanges, due to the absence of strap *Y*. In these circumstances relay *L* operates from the battery at ***P4*** via the loop to the earth at ***P1***.

If, on an outgoing call from the U.A.X., a subscriber dials a "barred" routing code, N.U. tone is returned to the caller. Whilst the subscriber holds the call, the junction is not engaged at the distant end and can be taken into use for an incoming call. Contact *K1* in conjunction with *P6* allows the subscriber to hold the connexion and receive N.U.T. when the junction is taken into use for an incoming call. When the caller hangs up, the ***B1*** earth is removed but the battery condition is still disconnected at ***K1***.

Fee Determination and Route Discrimination. The multi-metering relay set associated (when required) with each junction relay set has three important functions:

(*a*) To determine the appropriate fee for every call and, when the called party replies, to apply the correct number of metering pulses to the calling subscriber's meter.

(*b*) To prevent a subscriber from dialling through other exchanges to obtain a call where the charge is in excess of the maximum 4 units for automatic registration.

(*c*) To bar all calls from coin-box subscribers to exchanges outside the unit fee radius.

It is clear that the above discrimination cannot be made until some or all of the routing digits have been dialled. It is therefore necessary to provide, in the multi-metering relay set, an impulse counting mechanism with a capacity sufficient to take all impulse trains up to the point where the terminal exchange is determined. That is, the mechanism must count all digits until a local level is selected at the distant exchange.

Fig. 422 shows the discriminating arrangements. The multi-metering uniselector (*MM*) is of the homing type and always starts from the first contact. The impulse trains passing over the junction are repeated at *A1* and are routed to the *MM* magnet via ***BD1***, *MH1*, *DB1* and the chain of *MA*, *MB*, *MC*, and *EF* contacts. The wipers of the uniselector are therefore moved one step per impulse irrespective of the grouping of the impulse trains. Three relays *MA*, *MB*, and *MC* are provided to apply the appropriate pulses to the subscriber's meter. The detailed method of application of these pulses to the junction relay set is described later but, for the moment, it may be assumed that the following combinations are required:

Single unit fee—relay *MB* operated.
Two units fee—relay *MA* operated.
Three units fee—relays *MA* and *MB* operated.
Four units fee—relays *MA*, *MB*, and *MC* operated.

The lower part of Fig. 422 shows how these combinations are obtained when an earth is applied to the appropriate fee terminal. Basically, it is necessary only to connect the required fee terminal to the bank contact to which the multi-metering uniselector has been stepped. The circuit can then be arranged so that, on the release of the *C* relay in the junction relay set, an earth is applied to operate the appropriate combination of *MA*, *MB*, and *MC*. This simple arrangement would cater for 25 dialling codes only, but apart from this, the scheme is impracticable due to the fact that the switch would be stepped to the same contact by all dialling codes which have the same total number of impulses. For example, if exchange *A* is in the unit fee area and requires the digits 532 (10 impulses in all), it is obviously impossible to cater for another exchange *B* which is in the 2-unit fee area and has a code 73 (10 impulses) before discrimination.

To obviate this difficulty, 5 selecting arcs are provided (*MM3*–*MM7*) together with 4 wiper switching relays (*SA*, *SB*, *SC*, and *SD*). The circuit is arranged so that on the release of *C3* at the end of each impulse train the marking earth can be switched at will from one wiper to the next by connecting the required switching relay to the appropriate bank contact. By this means the one multi-metering uniselector can accommodate sufficient dialling codes to meet the requirements of all except the more complex junction networks.

In addition to the selection of the appropriate metering pulses, the relay set also provides the following facilities:

(*a*) All spare and "barred" codes are connected to terminal "*SP*" and when such a code is dialled relays *EF* and *MC* operate. ***EF3*** disconnects the

hold circuit of the *HJ* relay in the junction relay set and the latter releases the junction at ***HJ*1** and ***HJ*2** (Fig. 420). Contacts ***EF*4** and ***MC*8** return N.U. tone to the caller.

(*b*) Dialling codes to manual exchanges in the unit fee area are connected to terminal *M* and, when a call is set up, relay *MC* operates. Contact ***MC*7** applies an earth to the manual hold relay ***EF*5** breaks the manual hold circuit for *C* (junction relay set) when the caller hangs up.

(*d*) If it is desired to bar access to a single fee junction from C.C.B. callers, the multi-metering uniselector bank contact is connected to terminal *IB*. When the call is from an ordinary line, this terminal is connected via *CB*7 to the normal single fee terminal and the call proceeds in the usual

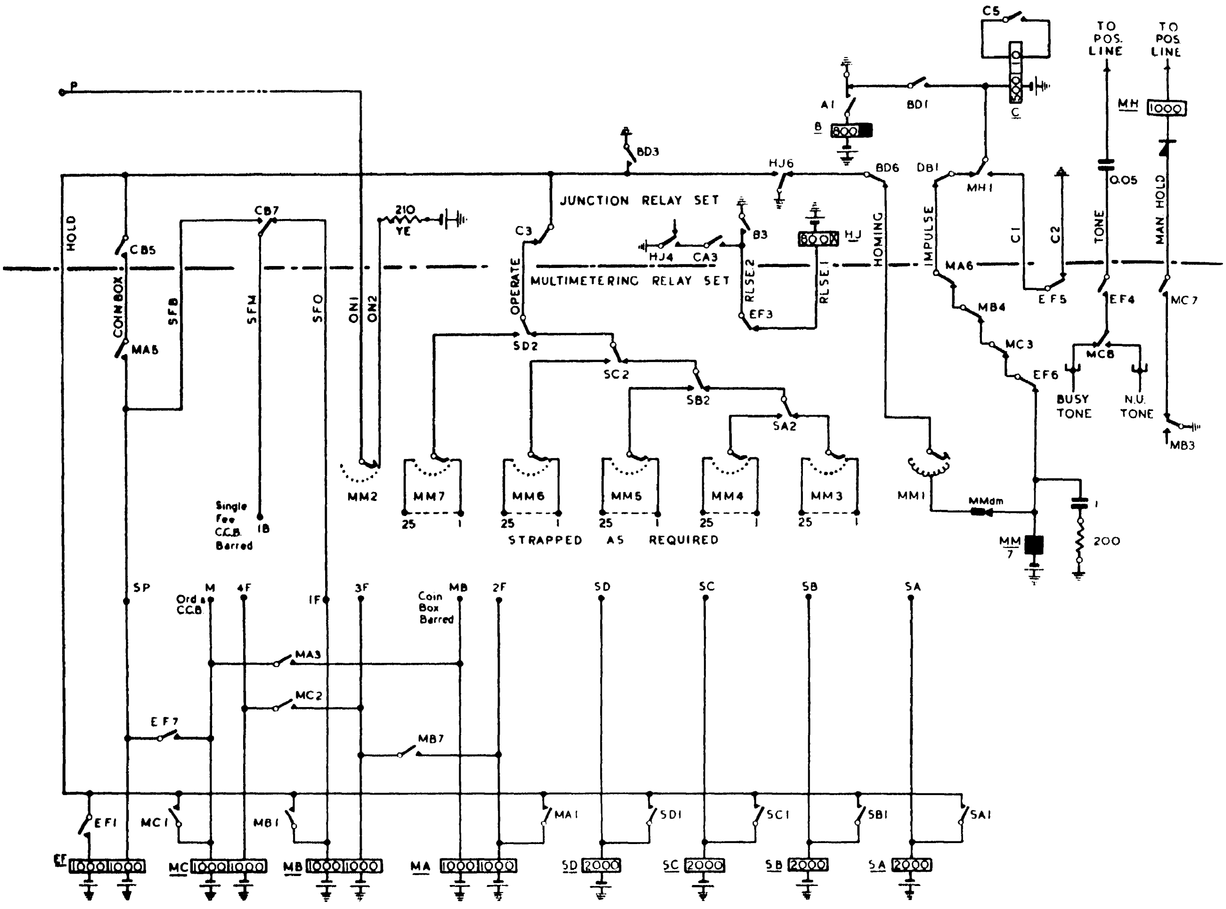


FIG. 422. MULTI-METERING RELAY SET

(*MH*) in the junction relay set to give the required holding facilities from the distant manual exchange.

(*c*) Dialling codes to manual exchanges in the multi-fee area are connected to terminal *MB*. When a code so connected is dialled, relays *MA* and *MC* operate in sequence. ***MC*7** provides manual hold as before, but, if the call originates from a coin-box, relay *EF* also operates from the earth at ***BD*3** (junction relay set) via ***CB*5** and ***MA*5**. ***EF*3** releases the caller from the junction, and ***EF*4** in conjunction with ***MC*8** gives N.U. tone.

way. When the call is from a coin-box subscriber, relay *CB* is operated and the *IB* terminal is connected to the *SP* terminal. In these circumstances *EF* and *MC* operate to release the junction and to give N.U. tone as already described.

After the setting up of a call, the wiper switching and discriminating relays lock to a common hold lead. At the end of the call, *BD*3 removes the earth from the hold lead to allow all relays to restore. At the same time a homing circuit for the uniselector is provided at *BD*6. The testing battery which indicates the free condition of the

junction relay set is fed via the home contacts of arc *MM*2. It is therefore impossible to re-seize the junction relay set until the multi-metering uniselector is fully restored.

Multi-fee Metering. It is very important with all forms of multi-metering to provide the maximum security against over-registration in the event of a fault. The metering elements of the junction relay set and the multi-metering relay set (Fig. 423) follow the principles already described in Chapter IX. Combinations of relays *MA*, *MB*, and *MC* are operated during the setting up of a call, and the selected relays are held until the connexion is released. When, on an outgoing junction call, the called party replies, relay *D* operates. ***D*3** completes the circuit for the first coil of *DA* to the *S* pulse in the meter pulse relay set. The *S* pulse is a battery pulse of 200 msec duration which starts the cycle of meter pulses. *DA* operates to the first *S* pulse and holds independently of the *S* pulse at ***DA*1** on its 1000 Ω winding. ***DA*2** prepares the circuit for the *Z* pulse, whilst ***DA*4** extends the *P*-wire in readiness for metering. Some 800 msec after the start of the *S* pulse, the *Z* pulse is applied. Relay *DB* now operates and the *DA* relay is held by the same current in its third winding. ***DB*3** removes the short circuit from the hold winding of *DB* whilst ***DB*4** extends the *P*-wire to the meter pulse circuit.

The metering pulses are of 200 msec duration and there is the same time between pulses. These pulses operate the subscriber's meter, relay *DA* being held by the *Z* pulse until after the completion of the last pulse. At the end of the cycle, the *Z* pulse terminates and releases *DA*. *DA*4 now disconnects the meter pulse lead but relay *DB* is held for the duration of the call. It will be noted that any flicking of relay *D* during impulsing cannot interfere with the metering cycle. If the call is released during metering, *B*1 short-circuits the hold coil of *DA* and cuts off the meter pulse train at *DA*4.

It will be recalled that the meters of coin-box lines are connected to battery instead of earth as on ordinary lines. Coin-box meters will therefore not respond to the battery metering pulses. Fortunately, multi-metering is not required on coin-box lines, and all calls for automatic registration are single fee. Relay *MB* is operated for single fee metering and an earth is extended to the *D*-wire via ***MB*3** and ***CB*3**. Thus the metering condition to a coin-box line is a single earth pulse of the same duration as the *Z* pulse.

Auxiliary Multi-metering Relay Set. It is sometimes necessary to provide additional equipment to supplement the normal multi-metering relay set. The equipment takes the form of an auxiliary relay set which is common to all multi-metering relay sets. The auxiliary equipment (Fig. 424) is extremely simple and contains only one 8-level uniselector (*MC*) together with a

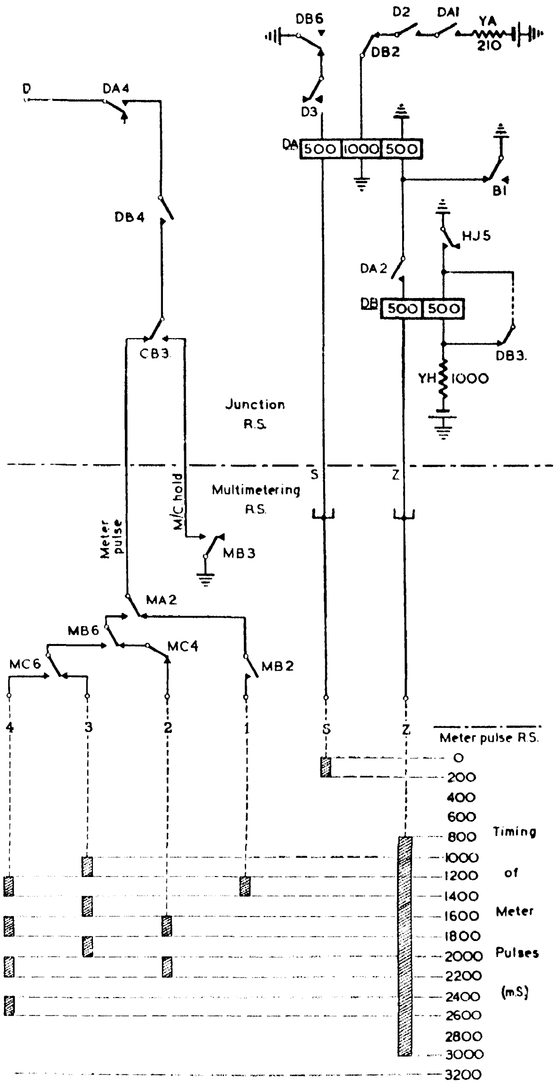


FIG. 423. CONTROL OF METERING

testing relay (*T*). There are no wiper switching facilities, but there are 7 leads (*MC*2–*MC*8) from each multi-metering relay set which can be strapped as required to any contact of the *MM* uniselector. When the *MM* uniselector is stepped to a contact so connected, the operating earth energizes relay *SE* in the junction *MM* relay set via the *SF* contact and *MA*, *MB*, *MC*, *EF*

contact chain. ***SE*3** and ***SE*4** apply the switching relay *K* to the test lead of the auxiliary R.S.

If the auxiliary equipment is busy, there is a 25 Ω earth on the *T*-lead and relay *K* cannot operate. ***SE*2** energizes relay *SF* which operates after a lag and ***SF*8** allows *EF* to operate via *K*2. ***EF*4** (Fig. 422) returns busy tone to the caller. ***EF*2** releases *SE*, and the relay set is locked out until the caller releases.

earth at *T*2, and when the wipers reach the normal position the testing battery is restored to make the equipment available for a second call.

Common Equipment. The common equipment of a U.A.X. 12 is concentrated into two jacked-in relay sets. The first, known as the *Tone and Time Pulse* relay set, contains the ringing and busy tone supply circuits, the release alarm circuit, and the time pulse uniselector circuit. The second relay set

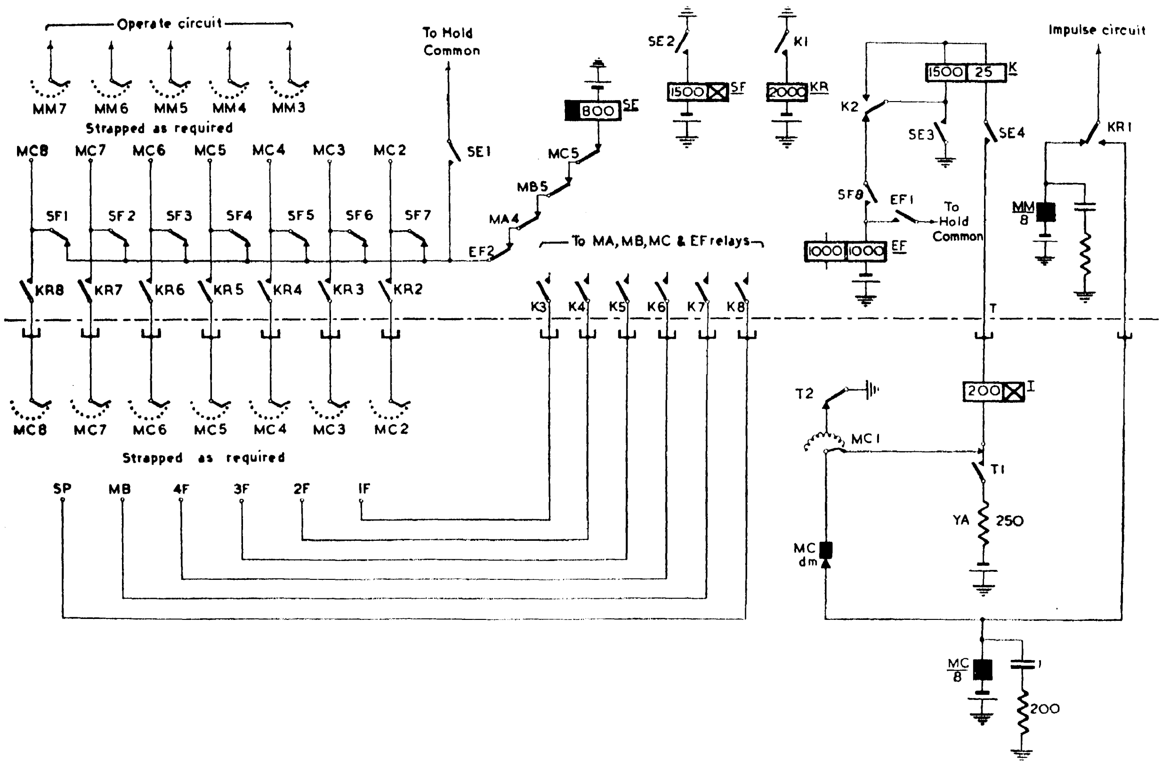


FIG. 424. AUXILIARY MULTI-METERING RELAY SET

If the auxiliary multi-metering equipment is free, *K* operates in series with the *T* relay. ***K*2** short-circuits the high resistance coil of *K* to provide a low resistance guarding earth on the *T*-wire. Relay *T* now operates and provides a holding circuit at ***T*1** independent of the driving magnet battery. ***K*1** operates the relief relay *KR* and ***KR*1** extends the impulsing lead to the auxiliary uniselector driving magnet. The remaining contacts of *K* and *KR* switch through the operate and discriminating leads.

When final discrimination has been made, one or more of relays *MA*, *MB*, *MC*, *MD*, and *EF* will be operated. Associated contacts break the circuit of *SE* which releases relays *K*, *T*, and *KR*. The auxiliary uniselector now homes from the

(the *Ringing and Meter Pulse unit*) includes the ringing supply circuit, the fuse alarm circuit, and a uniselector which supplies pulses for metering, time pulse release, ringing and busy tone interruptions. The equipment of the two relay sets is considered on a functional basis in the following paragraphs.

Time Pulse Release. Facilities are provided to release a selector or junction relay set after a delay period should

(*a*) the selector be seized but not switched to a local or junction level,

(*b*) the calling party hold the call after the called subscriber has cleared (C.S.H. conditions).

Fig. 425 shows the elements of the release circuit. After the operation of *KF* (when the

linefinder switches a caller to a free selector), relay *TM* is applied to the time pulse start lead until such time as the selector discriminates to a local level (*MC* operated) or to a junction (*JC* operated). Similarly, this circuit is completed when the called subscriber hangs up (*D*4 released).

If the uniselector wipers are on any contacts other than the 1st, 8th, or 15th, relay *TA* operates on its 6500 Ω coil to the earth at *JC*7 via the *TP*2 arc. ***TA*1** starts the pulse circuit which delivers earth pulses to the *TP* driving magnet every 5 sec. Relay *TM* does not operate over the start circuit due to the high resistance of *TA*.

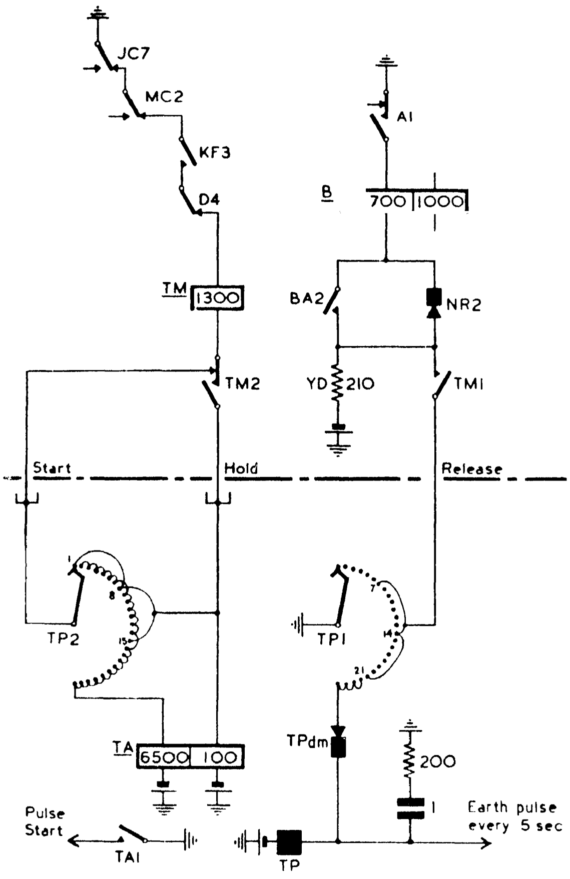


Fig. 425. Time Pulse Release Element

In due course, the wipers are stepped to the 1st, 8th, or 15th contact and the 100 Ω coil of *TA* is applied to the start wire. *TM* now operates and is maintained at ***TM*2** over the "hold" lead. ***TM*1** prepares the "release" lead to the *B* relay. The *TP* uniselector continues to drive, and after 6 further steps earth is applied to the release lead from the *TP*1 arc. This earth shunts out the battery supply to the *B* relay and both *B* and *BA* release. *B* releases *KF* (Fig. 407) and the selector is freed.

The time delay for forced release is dependent upon the position of the *TP*2 wipers when the

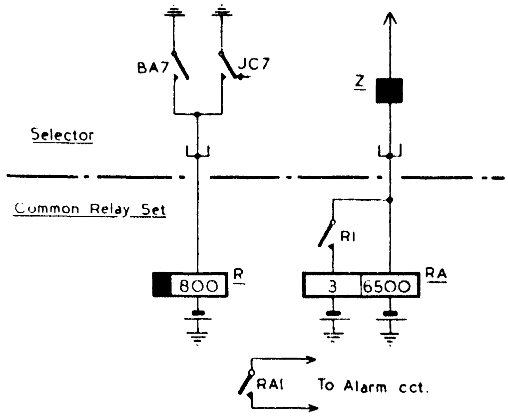


Fig. 426. Release Alarm Circuit

start condition is received, i.e. the release delay may be from 30 to 65 sec. There is a further arc (not shown) of the *TP* switch which is used for the forced release of junction relay sets. The circuit arrangements are similar to Fig. 425, but the arcs are commoned so that a time delay of from 90 to 190 sec is introduced.

Release Alarm. Fig. 426 shows the release alarm circuit which is designed not only to give an alarm if a selector fails to restore, but also to reduce the current in the release magnet to prevent overheating under prolonged fault conditions.

When a selector is seized, relay *R* operates to an earth applied at ***BA*7** or ***JC*7** (see Fig. 407). ***R*1** places the low resistance winding of *RA* in parallel with the high resistance winding, thereby providing a release circuit of low resistance. Relay *R* is slow-to-release to cover the release time of the selector, and, if the *Z* circuit is still maintained when *R*1 releases, the current in the release magnet is reduced to a very small value. Relay *RA* holds (on its 6500 Ω winding) to the reduced current and gives an alarm at ***RA*1**.

Meter Pulse Uniselector. The meter pulse uniselector is driven by three interacting relays *X*, *Y*, and *Z* (Fig. 427). When a start condition exists *MS* operates and energizes relay *X*. ***X*1** breaks the circuit of *Z*, and *Z*1 allows *Y* to operate. ***Y*1** now disconnects *X*, and *X*1 on release closes the circuit for *Z*. After a few cycles, relays *X*, *Y*, and *Z* settle down to a regular cycle of operations. The non-inductive shunts are chosen

to give release lags such that each cycle takes approximately 200 msec. Contact $X1$ controls the

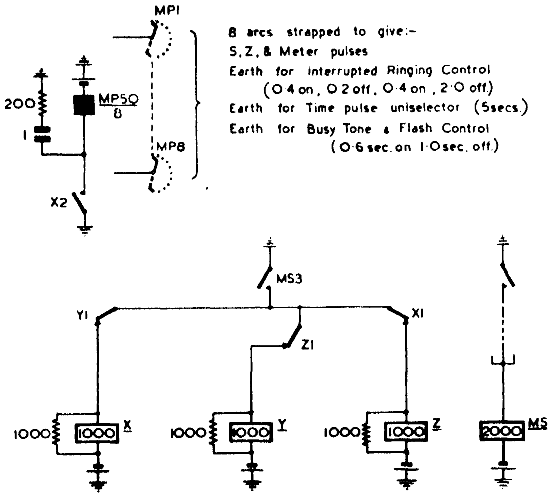


FIG. 427. PULSE GENERATION CIRCUIT

stepping of the uniselector which thus rotates at approximately 5 steps per second. There are 8 arcs to the uniselector and these are commoned to provide the required pulses.

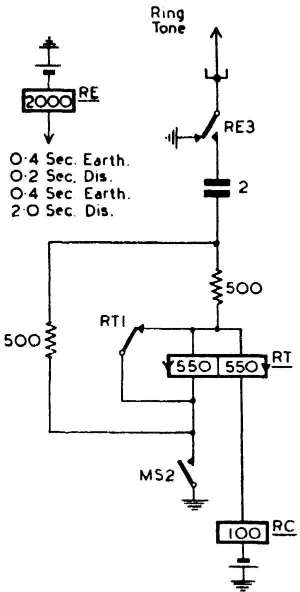


FIG. 428. RINGING TONE CIRCUIT

Ringing Tone Supply. Ringing tone is generated by a mechanically tuned vibrating relay (RT). When the start contact ($MS2$) is closed (Fig. 428), the RT relay operates over one coil to the battery at RC. RT is differentially wound, and, in operating, the interrupter contacts ($RT1$) remove the short circuit from its second winding. The opposing magnetic force of the second winding therefore causes the relay to release. $RT1$ remakes and the cycle is repeated approximately 133 times per second. The tone is picked up from the common point of the RT windings. It is clear that, during the operation of RT, the potential at this centre point changes rapidly from earth to about 20 volts negative. The two 500 Ω resistors are introduced to cut down the tone level and to provide a spark quench for the $RT1$ contact. The impedance coil RC isolates the tone from the battery supply.

The transmission of ringing tone is controlled (at $RE3$) by the RE relay which is in turn operated

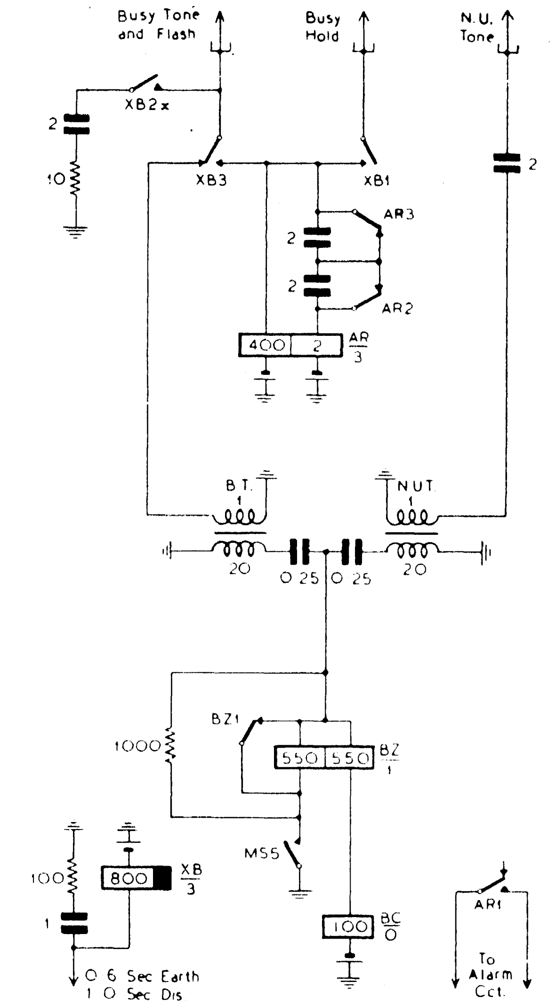


FIG. 429. BUSY TONE AND NUMBER UNOBTAINABLE TONE SUPPLY CIRCUIT

in the standard ringing sequence by suitable commons on an arc of the meter pulse uniselector.

Busy and N.U. Tone Supply. Fig. 429 shows the supply circuit for busy and N.U. tone. The tone relay BZ is similar to the ring tone relay previously described but is mechanically tuned to a frequency of about 400 c/s. The tone is fed to two transformers BT and NUT and the supply

is taken from the secondary windings. Interruption of the busy tone is obtained by relay *XB* which is energized from the meter pulse uniselector for 0·6 sec and disconnected for 1·0 sec. *XB* is made slow-to-release to prolong the make period and so to obtain a changeover of the *XB* contacts at regular intervals of approximately 0·8 sec. *XB*3 provides the interruptions for busy tone and flash, whilst *XB*1 controls the busy hold. Relay *AR* does not normally operate except when an earth fault develops on the flash, tone, or hold leads. In these circumstances ***AR*2** and ***AR*3** prevent the

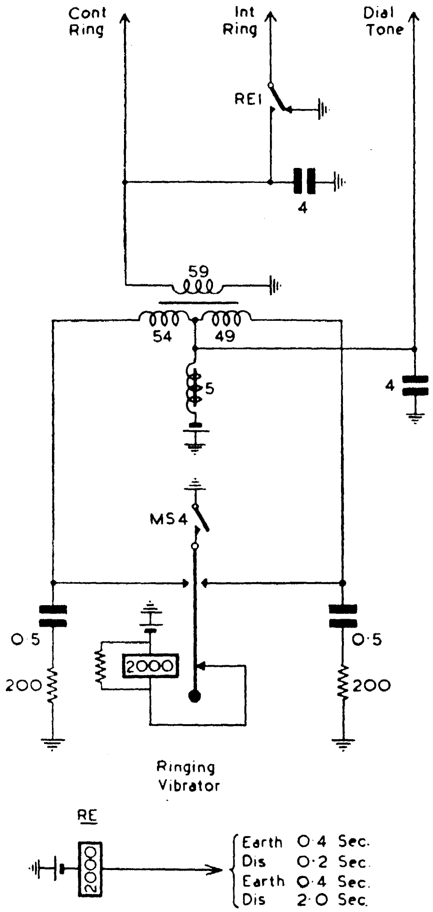


Fig. 430. Ringing and Dial Tone Supply Circuit

blowing of the supply fuse or the overheating of the relay. ***AR*1** gives an alarm.

Ringing and Dial Tone Supply. The ringing generator is a vibrator of the "bobble" type which works on the trembler bell principle with a natural frequency of approximately 20 c/s. Additional contacts of the vibrator send current alternately through the two primary windings of the transformer thereby giving an alternating current supply in the secondary circuit (Fig. 430). Relay

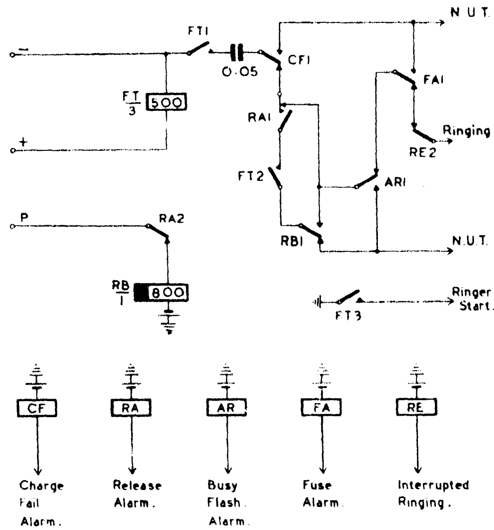


Fig. 431. Test Number Circuit

RE is operated from the meter pulse uniselector at the standard ringing periods, and *RE*1 interrupts the ringing supply to the selector circuits. Spark quench circuits are provided for the vibrator contacts and an additional 4 μF capacitor in the secondary of the ringing supply shunts away the higher frequency harmonics of the tone.

The dial tone is obtained by tapping the potentials across the 5 Ω choke in the common battery feed. The pulses of current in this choke are of double the ringing frequency and hence the tone is of some 40 c/s.

Test Number Circuit. It has already been stated that there is no provision for the extension of alarms from a U.A.X. 12. In place of this, a special test number (usually 299) is provided which will give a distinctive tone to a testing operator if urgent fault conditions exist. Relay *FT* (Fig. 431) operates when the test number circuit is seized, and (if *RA* is not operated) the earth on the *P* wiper energizes *RB*. If no faults exist, ***FT*1** connects ringing to the negative line via the 0·05 μF capacitor. This tone is interrupted by contact ***RE*2** which (being a break contact) closes the circuit for 2 sec and disconnects the tone during the normal periods of ringing. The tone is therefore the reverse of ringing tone and is very distinctive.

If a charge fail, release, busy flash, or fuse alarm

exists, contacts ***CF*1**, ***RA*1**, ***AR*1**, or ***FA*1** switch the tone from inverted ringing to N.U. tone. The *RB*1, *RA*1, and *RA*2 contacts are arranged so that interruptions of the tone do not occur due to flick operations of *RA* during the normal release of selectors.

Routine Testing. One of the line circuits (usually that of the exchange service telephone) is provided with test jacks and an additional relay *RT*. The connexion of a lineman's portable telephone to one of the test jacks (*TA*) enables simple functional tests to be made, whilst a portable tester used in conjunction with the second test jack (*TB*) provides for more comprehensive tests. The routine test circuit has been omitted from the

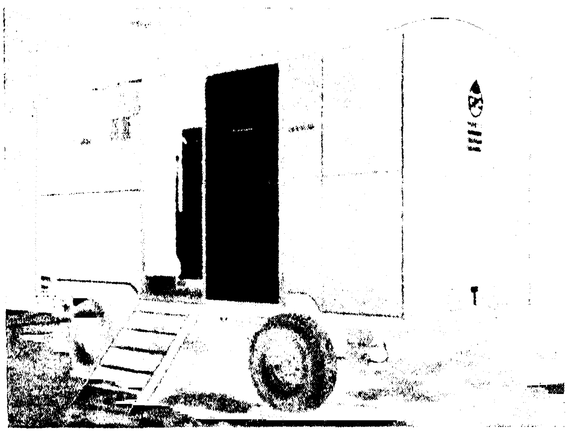


FIG. 432. GENERAL VIEW OF MOBILE U.A.X.

various circuits given in this chapter to avoid undue complication.

Mobile Automatic Exchanges. It is often necessary to replace a small manual exchange at very short notice due to the inability of the Caretaker Operator to continue service as the result of illness, death, or any other unforeseen circumstances. Although the unit principle of construction materially reduces the time taken to install automatic equipment, there is generally a period of some months before a new U.A.X. can be brought into service. Sometimes difficulties are encountered in obtaining a suitable site for the U.A.X. and, when this has been arranged, there may be building delays.

It was decided that it would be desirable to have a number of small mobile automatic exchanges to meet sudden demands. Apart from their use in cases where a Caretaker Operator can no longer continue service, the mobile exchanges are of value for the replacement of small exchanges which may be damaged by fire or flood, and also to augment the existing telephone service in an area where there is unexpected development.

The standard mobile automatic exchange makes provision for 90 subscribers and 10 junctions, and incorporates the necessary batteries, charging plant, and all the other facilities necessary at a small automatic exchange. The design is based on the standard U.A.X. 12 equipment, and the complete unit is entirely self-contained and is fully mobile.

Fig. 432 gives a general view of a mobile automatic exchange (M.A.X.). The chassis is a 4-wheel trailer with independent torsion bar springing on each of the four wheels. The two front wheels are mounted on a turntable which permits them to rotate through an angle of some 45° on either side of the normal position. The Ministry of Transport regulations require an independent control of the trailer brakes when the unit is on tow. A brakeman's cabin is therefore provided, and in addition there is a second brake lever (located on the near side of one of the main chassis members) for use as a parking brake when the trailer is being manually manoeuvred into position. The brakes are of the Lockheed hydraulic type and operate independently on all four wheels.

The weight of the complete vehicle (including equipment) is just under 6 tons. When the mobile exchange has arrived at its temporary site, the pneumatic tyred wheels are replaced by heavy cast steel feet which are bolted on to the axles in place of the wheels.

The trailer body is fabricated from steel sheets which are welded together to give a unit of the greatest possible strength. Particular care is taken to provide adequate protection against rust. The floor of the trailer is specially strengthened where the main weight of the automatic units is applied. In order to make the centre of gravity as low as possible, the floor is sunk to a distance of some 6 inches below the tops of the wheel arches. The equipment is positioned, however, so that the flat topped wheel arch projections do not interfere with the ease of access to the equipment. The exchange has a sheet steel lining with 1 in. of cork insulation between the inner and outer steel shells.

Fig. 433 shows the lay-out of equipment inside the trailer. The brakeman's cabin is accessible only from an outside door which is normally locked when the exchange is on site. The space under the brakeman's seat is utilized to provide a locker. A second locker is provided under the power board on the opposite side of the vehicle. The batteries are accommodated in two separate

boxes over the rear arches. Each box accommodates twenty-five 72 ampere-hour cells of the traction type to give a total battery weight of approximately half a ton. The power board is arranged for charge-discharge working with facilities for charging from the engine or from a.c. mains via a Tungar rectifier. The engine consists of a 2 h.p. water-cooled single-cylinder petrol engine directly coupled to a 500 W d.c. generator. The whole unit is mounted at the forward end of the vehicle on anti-vibration fittings.

on each side of the units. The underground cable is led into the vehicle through a flexible steel tube and is terminated on a special mechanical joint fixed on the rear end wall. The switchboard cables connect the external lines from this point to the M.D.F. in the C unit.

The time taken to bring a mobile exchange into service is dependent mainly upon the time required to convert the subscribers' apparatus and to extend the lines to the temporary site. In ordinary circumstances it is usually possible to provide

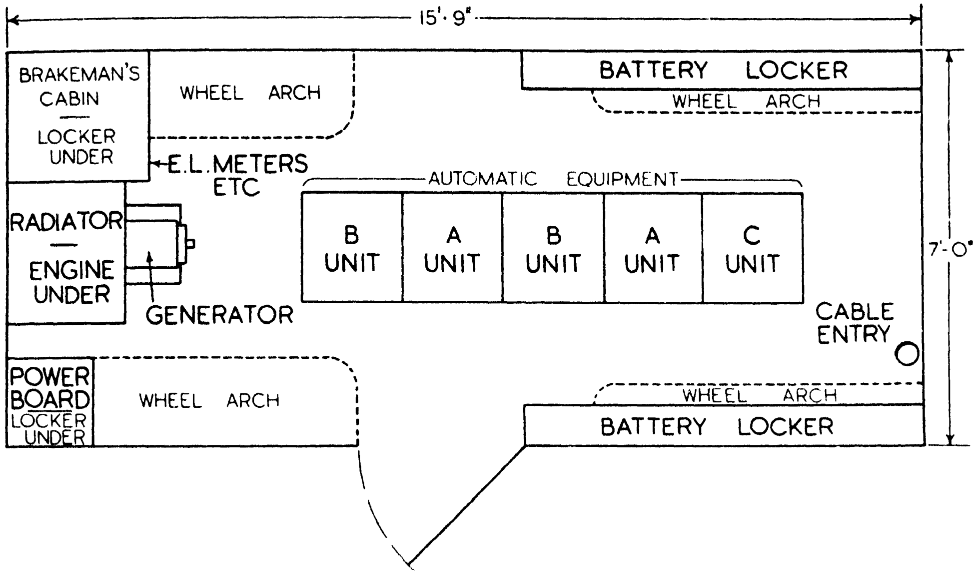


FIG. 433. LAY-OUT OF EQUIPMENT IN MOBILE AUTOMATIC EXCHANGE

On account of the difficulty of providing space for a large water tank, provision is made for radiator cooling of the engine water. The fan-cooled radiator is located in an enclosed box above the engine with suitable ducts for obtaining a good circulation of air. The heated air, after passing through the radiator, flows through an enclosed duct which terminates at a louvred outlet high up in the end wall. Arrangements are made for the collection of rain water from the roof of the vehicle in a special tank beneath the floor, a semi-rotary hand pump being provided to fill the radiator system. A 2-gal petrol tank is built into a small cubicle accessible only from the outside of the vehicle.

The automatic equipment consists of one C unit, two A units and two B units of the standard No. 12 equipment. The complete suite of five units forms a rectangular block some 9 ft long and 6 ft 4 in. high. The suite is located centrally in the vehicle to provide gangways of some 2 ft 6 in.

service within a fortnight of the delivery of the vehicle.

Earlier Models of Small Type U.A.X.s. Prior to the introduction of the standard U.A.X. 12, several U.A.X.s of similar capacity were installed at various localities on an experimental basis. The superseded systems were known as the U.A.X. 5 and the U.A.X. 11 and, although they are gradually being replaced by standard equipment, a number of each type still remains in service.

U.A.X. No. 5. The U.A.X. 5 has a maximum capacity of 100 lines (including junctions). The essential components are a uniselector type line-finder and a pre-2000 type selector. It employs a 2-digit numbering scheme for the subscribers (10–98) and provides facilities for three outgoing junction routes (including the parent route) by the use of 2-digit dialling codes. The system does not provide tandem dialling, trunk offering, multi-metering or P.B.X. facilities. In the interests of simplicity there is no dial tone, and a

non-standard form of ringing tone is employed. Another unusual feature is that the subscriber must dial "01" to obtain access to the parent exchange operator. The exchange is made up of enclosed type units, each unit providing sufficient linefinders and selectors, etc., for 25 lines. Unlike the U.A.X. 12, the M.D.F. is not enclosed.

U.A.X. No. 11. The U.A.X. 11 employs the switching principles of the Bypath system (q.v.). (It is sometimes known as the Bypath system type R.) It has a capacity of up to 80 lines, and utilizes large 50-point uniselector mechanisms both for linefinding and selection. The unit allows interdialling and gives P.B.X. facilities, but does not make provision for tandem dialling, trunk offering, or multi-metering. The parent exchange operator is obtained by dialling "0," whilst the subscribers' numbering range is 200–229, 290–299, 300–329, and 390–399. Provision is made for the dialling of a single code digit to obtain access to an adjacent exchange, and the combined "9" and "0" level working described for the U.A.X. 12 is used. The U.A.X. 11 provides standard tones. The exchange is made up of self-contained 30-line units and, like the U.A.X. 5, the equipment is accommodated in a standard A type building.

Country Satellite Exchanges. In general it is economical to install U.A.X. 12 equipment only when there are 8 or more prospective subscribers. Smaller rural communities can be served by means of a call office at a central location and connected by an overhead line to the nearest public exchange. In some circumstances it is possible to provide a party line with up to 12 subscribers. Such rural party lines require a system of code ringing and do not provide secrecy. They are, moreover, not suitable for working to an automatic system, and it has been the policy in the past to discontinue rural party lines as far as possible on the conversion of an exchange to automatic working. In cases where it is necessary to retain a party line, the circuit is usually terminated on the automanual switchboard.

A scheme, utilizing what is known as a *country satellite exchange* (C.S.X.), was developed some years ago to provide service to small rural communities. The country satellite exchange is a very small unit which can be mounted on a convenient pole near the centre of the area to be served. It provides for up to 10 subscribers, who are connected to the C.S.X. unit by individual pairs, whilst the whole system is served by a single pair of wires to the nearest manual exchange. The circuit arrangements provide for secrecy on any call and, on incoming calls, for the ringing current to be directed only to the required subscriber's line (i.e. there is no code ringing).

The country satellite exchange consists of one relay per subscriber's line, together with a group of discriminating relays which can respond to signals from the manual exchange and thereby select any required line on the country satellite. There is no power plant at the country satellite exchange—all current for the operation of the relays being supplied over the junction pair. A complete 10-line country satellite exchange consists of some 25 relays which are arranged as "jacked-in" units. The equipment is made up into 5-line units which are mounted in a weatherproof box specially designed to exclude moisture and dust. At the parent exchange there is one common answering jack, one individual jack per subscriber, and a "revertive calls" jack which is required when a subscriber on the country satellite exchange desires a call to another subscriber on the same unit. The equipment at the parent exchange includes a uniselector which is connected to send out suitable code signals for the operation of the appropriate relays at the country satellite exchange.

If the junction is free, a d.c. loop formed by the lifting of the subscriber's receiver extends his earth connected line relay to the *B*-wire of the junction. This wire terminates on a battery connected line relay at the manual exchange, and both relays now operate. The line relay at the manual exchange lights the calling lamp, whilst the operation of the C.S.X. subscriber's line relay extends the telephone loop to the junction pair. Other contacts of the C.S.X. subscriber's relay prevent any other subscriber on the exchange from seizing the junction. A distinctive tone is now returned to the calling subscriber to indicate that the junction has been seized—the absence of this tone indicates to any other calling subscriber that the junction is engaged.

In due course the operator answers by inserting her plug into the common answering jack. The calling lamp is extinguished, and the tone is disconnected. The subscriber now gives details of the number required and his own telephone number. If the required line is not connected to the same country satellite exchange, the call is completed via the calling cord in the usual manner. If, however, the called subscriber is on the same exchange, the operator inserts the calling plug into the multiple jack of the required subscriber, and then removes the answering plug from the common answering jack. This operation disconnects the calling subscriber from the junction and selects the called subscriber, who is rung from

the calling plug in the usual way. When the called subscriber answers, the operator inserts an answering plug into the "revertive calls" jack and thereby reconnects the calling subscriber to the junction. Both subscribers are now in communication.

On calls incoming to country satellite exchange subscribers, the operator inserts the calling plug into the appropriate multiple jack of the required line. The insertion of the plug causes the uni-selector (at the manual termination) to step over its bank contacts under the control of a pair of interacting relays. As the wipers pass over the bank contacts, a series of discrimination signals are passed over the *A*-wire of the junction to operate one or more of the discriminating relays at the country satellite exchange. Contacts of these relays in turn operate the appropriate line relay, and the required subscriber's line is thereby extended to the junction pair, the operator calling the subscriber by the operation of the ringing key in the usual manner. The discriminating signals consist of combinations of heavy and light currents from − and + batteries located at the exchange. Differentiation between the various signals at the country satellite exchange is obtained by the use of rectifiers and marginal adjustments on the discriminating relays. The code used is as follows:

Subscriber 1.	Light + ve
Subscriber 2.	Heavy + ve
Subscriber 3.	Light − ve
Subscriber 4.	Heavy − ve, light + ve
Subscriber 5.	Heavy − ve, heavy + ve
Subscriber 6.	Heavy − ve, light − ve
Subscriber 7.	Heavy − ve, heavy − ve, light + ve
Subscriber 8.	Heavy − ve, heavy − ve, heavy + ve
Subscriber 9.	Heavy − ve, heavy − ve, light − ve
Subscriber 10.	Heavy − ve, heavy − ve, heavy − ve

The country satellite exchange scheme does not provide for metering or trunk offering. Moreover, only post-payment coin-box lines may be connected, and it is not possible to have certain of the recognized plan numbers. Designs are available for working to C.B.S. 1, C.B.S. 2, C.B., and sleeve control automanual exchanges. The system cannot of course, be used unless there is a manual board at the parent exchange.

EXERCISES XIV

1. Draw a diagram showing the trunking arrangements at a standard type of unit automatic exchange. Enumerate the service facilities afforded by the equipment. (*C. & G. Telephony, Grade III*, 1938.)

2. Describe, with the aid of suitable sketches, the construction and lay-out of the three standard units from which a U.A.X. 12 exchange is built up. Give a diagram to show, on broad lines, the cabling between the various units and the method of interconnecting the subscribers' calling equipments and the selector multiple.

3. A certain U.A.X. 12 consists of one A unit which is equipped with four connecting links. If the traffic on the exchange is 0·75 T.U. during the busy hour, calculate the grade of service. What would be the grade of service (with the same traffic) if one of the selectors were placed out of service due to a fault? Show by means of a simple diagram how you would "busy" such a faulty selector to prevent its seizure by a calling subscriber.

4. Show by means of a suitable diagram how, in a U.A.X. 12, a calling subscriber is connected to a free selector circuit. What provisions are made to minimize the danger of a calling subscriber commencing to dial before the selector is ready to receive the impulse trains?

5. In a unit automatic exchange a vertical marking bank is provided on the selectors to discriminate between calls

(*a*) to local subscribers,

(*b*) to the parent automatic exchange,

(*c*) to the parent automanual board,

(*d*) to adjacent automatic exchanges with unit fee metering, and

(*e*) to automatic exchanges with multi-fee metering.

Explain how this discrimination is effected, and give diagrams of the various circuit connexions to the vertical marking bank. (*C. & G. Telephony, Grade III*, 1946.)

6. Describe, with reference to a simple diagram, the circuit principles whereby calls to level 9 and level 0 of first selectors in a 100-line Unit Automatic Exchange are routed over a common group of junctions to the parent automatic and automanual equipments respectively. What electrical conditions are applied to the junction line to provide "manual hold"? (*C. & G. Telephony, Grade III*, 1944.)

7. A caller at a coin-box telephone connected to a unit automatic exchange dials "0." Explain how the operator at the parent exchange is notified that the call originated from a coin-box station. Give a diagram of the circuit elements concerned at both ends of the junction. (*C. & G. Telephony, Grade III*, 1945.)

8. *Explain (with diagrams) what happens in a U.A.X. 12 if*

(*a*) there is a low resistance earth fault on the − wire of a subscriber's line,

(*b*) the − and + wires of a subscriber's line are short-circuited but there is no earth fault on the line.

9. *Using a simplified circuit diagram,* describe the manner in which trunk offering facilities are afforded at a unit automatic exchange of modern type. (*C. & G. Telephony, Grade III*, 1943.)

10. Explain how the correct fee is determined at a U.A.X. 12 when a call is set up to a distant exchange. How are coin-box subscribers barred access to multi-fee routes?

CHAPTER XV

THE UNIT AUTOMATIC EXCHANGE NO. 13

THE No. 13 type Unit Automatic Exchange was originally designed for use at rural centres where the anticipated number of subscribers exceeds the capacity of the No. 12 equipment, or where tandem dialling facilities are required. Although the equipment was originally intended to cater for a maximum of 200 subscribers, it is possible to extend this capacity by utilizing additional levels of the group selectors for local traffic. This does, of course, reduce the number of junction dialling codes available, but the expedient has been adopted as a post-war measure to avoid exchange conversions (with the resultant building and equipment problems). It has now been decided that U.A.X.s of the No. 13 type can be extended to cater for up to a maximum of 400 lines if this can be done without prejudice to the junction requirements of the exchange. The additional units can be accommodated either in an extension of the existing building or in a separate building alongside the original exchange. Such exchanges are known as the "Extended No. 13" type or as "U.A.X.s No. 13X."

The equipment is enclosed in airtight cabinets for installation in unheated buildings. All relays are of the 600 type or the 3000 type with twin contacts, whilst the 2-motion selector mechanisms are of the 2000 type. Battery testing principles are employed at all switching stages.

Facilities. The more important facilities provided by the No. 13 equipment are:

(1) Normally, the capacity is limited to 200 subscribers' lines and 40 junctions, with a maximum of 6 junction routes (including the parent exchange route). The equipment is designed to cater for a total busy hour traffic of 12·6 T.U. (This includes all originating, incoming, terminating and through traffic, but excludes through "0" level traffic.)

(2) The capacity of the exchange can be increased up to a maximum of 400 subscribers and 80 junctions if not more than 4 outgoing junction routes (including the parent) are required. Such an extension is, however, permissible only if the volume of traffic is within the capacity of the maximum number of selectors provided for in the design of the equipment. Usually the load of the group selectors is the determining factor. The maximum number of such selectors is 8 for each unit of 50 subscribers and 10 junctions. The total traffic on such a unit must, therefore, not exceed about 3·15 T.U.

(3) The exchange can be built up gradually as required by the fitting of additional units. The installation of the first unit makes available 100 multiple numbers, but the number of subscribers is limited to 50 by the number of calling equipments. This first unit provides for 10 incoming junctions. The addition of a second unit increases the number of calling equipments to 100 subscribers plus 20 junctions, but the total multiple capacity remains the same, i.e. 100 lines. The addition of a third unit increases the multiple capacity to 200 with a total of 150 subscribers plus 30 junctions. The addition of a fourth unit (the final unit for a normal No. 13 exchange) increases the total calling equipments to 200 with provision for 40 junctions. The exchange can be still further extended, each pair of units adding 100 multiple and 100 calling equipments.

(4) The subscribers' numbering range is 200–299 and 300–399. Unlike the U.A.X. 12, this numbering scheme is unaffected by the junction requirements. No. 299 is, however, reserved as a fault test number, and 290 is usually allocated to the service telephone. Nos. 399 and 390 are also used for routine testing, and it is preferable to avoid, for as long as possible, the allocation of these numbers to subscribers.

(5) Provision is made for access to a maximum of 6 outgoing junction routes (including the parent route) by the dialling of single digit codes. Digit "0" does, of course, give access to the parent exchange operator, whilst "9" gives access to the automatic equipment at the parent centre. Other non-parent routes are given dialling codes 4, 5, 6, 7, or 8.

(6) The subscribers' numbering range of the 13X exchange is:

200–299	400–499
300–399	500–599

The extended subscribers' numbering range prevents the use of the digits 4 and 5 for outgoing junction routes, and restricts the number of such routes to 4 (including the parent route). No. 499 is required as a second fault test number, whilst 490 may be required for a second service telephone. Nos. 599 and 590 are used for routine test purposes

and should be allocated to subscribers only when no other spares are available.

(7) The equipment provides standard balanced tones in accordance with non-director 2000 type exchange practice. Dialling tone is also given to operators on all incoming junction calls.

(8) Ballast type transmission feeding bridges are provided.

(9) Facilities for P.B.X.s of up to 10 lines are available throughout the numbering scheme.

(10) Provision is made for the forced release of the common equipment in from 1 to 5 min if the following conditions persist:

Permanent loop (or P.G.)
Called subscriber held
Spare level dialled.

Forced release also occurs in from 3 to 6 min if an outgoing junction is seized but not used.

(11) A combined group of junctions is used to the parent exchange. The signalling arrangements provide for discrimination between ordinary and coin-box calls, and between calls which are to be routed to the parent manual board or the parent exchange automatic equipment. The first two junctions of the parent route are alternated on the banks of the group selectors, so that a different junction is taken into use on successive attempts.

(12) The subscribers can obtain the attention of the parent operator by the use of a single digit "0" even if the U.A.X. is not directly connected to the parent exchange.

(13) Subscribers on exchanges dependent upon the U.A.X. 13 can also obtain the parent operator by the use of a single digit "0." The circuit arrangements are such that differentiating signals are passed through the No. 13 equipment on calls from coin-box and ordinary lines, and also to distinguish between calls for the parent switchboard or the parent automatic equipment.

(14) The manual hold facility is provided on calls from both ordinary and coin-box subscribers to the parent switchboard. Manual hold is also provided on calls from ordinary subscribers to other (non-parent) manual exchanges (except where the call is routed through non-director automatic equipment at an intermediate point).

(15) Facilities are provided for automatic metering up to 4-unit fees and for the barring of coin-box calls from multi-fee routes.

(16) Trunk offering facilities are provided from the parent exchange to a directly connected U.A.X. 13. These facilities are not available if the parent exchange is indirectly connected through distant non-director automatic equipment. Trunk offering can also be made available (exceptionally) from non-parent exchanges.

(17) Overflow meters are provided to record congestion on group selector levels and on the linefinder groups.

(18) No provision is made for the extension of the exchange fault alarm system, but a fault test number is provided so that the parent operator can ascertain the conditions at the U.A.X. by the dialling of this number. If conditions are normal, the telephonist receives inverted ringing tone. The absence of this tone, or the presence of N.U. tone on the fault test number, indicates irregular conditions at the U.A.X.

Trunking Scheme. Fig. 434 shows the main trunking arrangements of a No. 13 type exchange. It is essentially a 3-digit scheme without absorption facilities. The first digit is received on a group selector, and the two final digits of the subscriber's number position the final selector on the required line. The group selectors are directly connected to 100-point linefinders of the 2-motion type.

The subscribers' lines appear on levels 3 to 8 of the linefinder bank; level 9 is reserved for routine test purposes, and level 0 is spare. Each linefinder group serves a total of 50 subscribers' line relays. Ten of these circuits appear both on level 7 and on level 8, the remaining 40 being spread over levels 3 to 6 inclusive. The line circuits associated with levels 3 to 6 can be used only for non-coin-box (i.e. ordinary) lines, but the 10 circuits which appear on both level 7 and level 8 can be used for either ordinary lines or coin-box lines. By means of a strapping scheme, it is possible to make any one of these 10 line circuits call either on level 7 or on level 8, depending upon whether the line is ordinary or coin-box. The linefinder is arranged so that, if the calling line is on level 8, a coin-box discriminating signal is forwarded to the group selector and the subsequent equipment.

Each linefinder group is served by two control relay sets and their associated allotter uniselectors. One control relay set serves the odd levels of the linefinder bank, whilst the other is brought into use when the calling line is located on an even level. Normally the allotters stand on outlets associated with free linefinders. When any subscriber calls, the line relay operates, and a start signal is sent to the appropriate control relay set. The control set now causes the free linefinder (preselected by the allotter) to search for the marked level and then for the marked contact in that level. When the calling line has been found, the call is extended to the group selector, and the control relay set is free for use on a second call. The allotter now steps forward until it is again standing on the

contacts associated with a free linefinder. Facilities are provided so that, if one of the control circuits or its associated allotter switch becomes faulty, the remaining control circuit takes over its functions. Similarly, any faulty linefinder is automatically busied out.

The incoming junctions are distributed as evenly as possible over the various linefinder groups of the exchange, where they appear on levels 1 and 2 of the linefinder banks. Each linefinder group will accommodate up to a maximum of 10 junctions. These 10 junctions appear both on level 1 and on level 2. As stated above, each of these 2 levels is served by a different control circuit and allotter. Normally the connexions are such that the 10 incoming junctions are divided evenly between levels 1 and 2. The incoming junction relay set, however, contains switching relays so that, if the normal calling level of that particular junction is, say, 1, and the appropriate control set for that level is engaged when a call originates, the marking condition is automatically transferred to level 2, so that the call can be dealt with by the remaining control set.

Any such incoming call may be routed from a selector level at a distant exchange, and it is necessary to ensure that the junction is associated with a free group selector at the U.A.X. within the interdigit pause period. (A considerable part of this period may already be absorbed by the rotary hunting time of the distant exchange selector.) The level switching feature provided on the U.A.X. 13 minimizes the possibilities of irregular routing should the normal control set be temporarily engaged on another call. The control sets also provide a pre-dialling path for incoming junction calls direct to the group selector until such time as the linefinder has searched for and seized the junction. The control set is now released as for a local call.

Level 1 of the group selectors is left spare in accordance with the usual practice on 1st selectors. The local final selectors are connected to levels 2 and 3, whilst levels 4 to 8 can be used as required to give access up to a maximum of 5 outgoing routes to non-parent exchanges. A single group of junctions to the parent exchange serves to carry traffic both to the parent exchange switchboard and to the automatic equipment at that centre. The parent junctions appear on both level 9 and level 0. If the group selector is stepped to the 9th level, the correct signalling conditions are passed forward over the junction to seize an incoming selector at the parent exchange. If, on the other hand, the group selector is stepped to level 0, a junction in the same group is seized but different signalling conditions are transmitted to indicate that the call is to be routed to the parent manual board.

In the 13X exchange, two additional final selector groups are provided to increase the multiple capacity of the exchange. These final

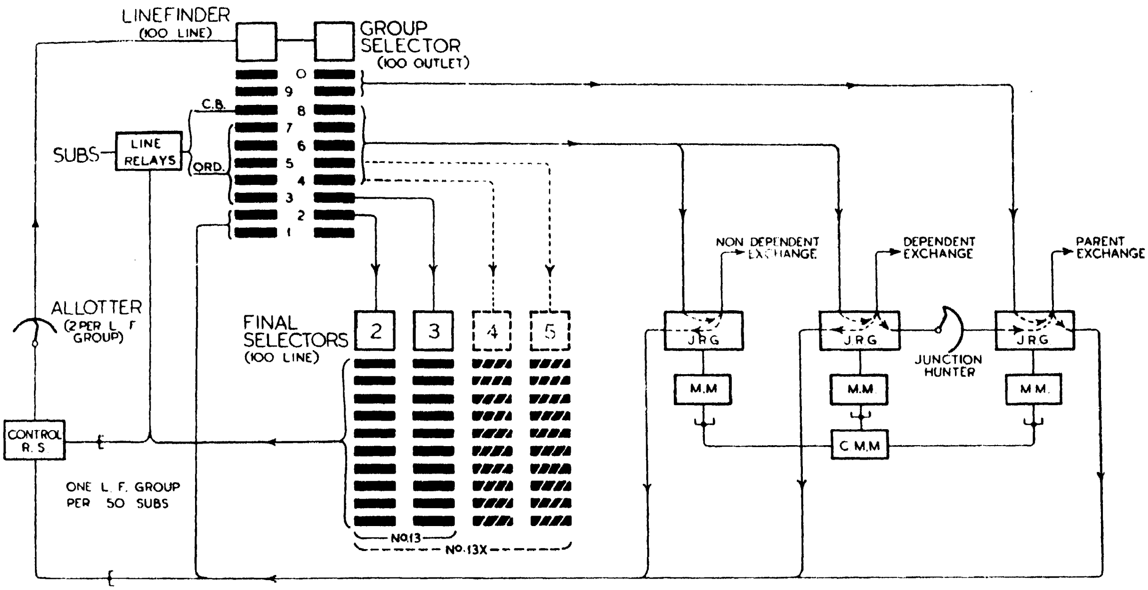


FIG. 434. TRUNKING SCHEME OF UNIT AUTOMATIC EXCHANGE NO. 13

(Parts shown by broken lines relate to equipment of U.A.X. No. 13X)

selector groups are connected to levels 4 and 5 of the group selectors, and hence these two levels are no longer available for outgoing junction routes. (The conditions are illustrated by the broken lines in Fig. 434.)

The junction relay groups (the relays, etc., are strip mounted in a U.A.X. 13) are of three main types. The circuits are usually arranged for bothway working although separate incoming and outgoing units are available for use where unidirectional working can be justified. One type of relay group is suitable for use on routes from non-dependent, manual or automatic exchanges. These circuits provide no differentiation on incoming calls, and the seizure signal merely extends the junction via a linefinder to a group selector at the U.A.X. It is then possible for the caller either to dial a local call or to interdial through the U.A.X. 13 to some distant centre. The outgoing portion of the non-dependent type relay group is connected to the appropriate level of the group selector, and operates much in the same way as an auto-auto relay set in the standard non-director system.

The relay groups which terminate the parent junctions are of a special type suitable for receiving discriminating signals from the linefinder and the group selector in order to distinguish between coin-box calls, ordinary calls, and calls which are to be routed to the parent exchange automatic equipment. As before, incoming calls from the parent exchange are passed via the linefinder to a group selector.

The third main type of junction relay group is specially designed for the termination of junctions from dependent exchanges (i.e. exchanges which have no direct route to their parent centre and which rely upon access through the U.A.X. 13 for such calls). Each relay group is provided with a uniselector known as a junction hunter. The banks of this switch give access to all the parent exchange junctions. Discriminating signals are passed forward from the dependent exchange to the U.A.X. 13 and, if these conditions indicate that a call is to be routed to the parent exchange manual board, the incoming junction is extended to the junction hunter which automatically searches for and seizes a free line to the parent centre. It will be noted that such calls do not engage any of the common switching equipment at the U.A.X. 13. The circuit arrangements provide for the repetition of coin-box discriminating signals so that, if a call originates from a coin-box line at a dependent exchange, the appropriate calling conditions are set up at the parent manual board. If the discriminating signals show that the call is to some point other than the parent manual board, the incoming junction is extended to a linefinder and thence to a group selector. The caller can then dial a local number at the U.A.X. or a further routing code digit.

Multi-metering relay sets can be provided as required on any outgoing junction. To economize in apparatus there are two main types of multi-metering relay set:

(*a*) The first and more simple type provides for fixed-fee metering and gives route restriction facilities if the caller attempts to dial any number which would extend him beyond the appropriate fee zone. This relay set is primarily used on junctions which carry terminal traffic only.

(*b*) The second form of multi-metering relay set is more complex and provides facilities for fee determination depending upon the routing digits dialled by the caller.

The multi-metering relay sets are provided (when required) on the basis of one per outgoing junction. In some cases it is not possible to cater for all the dialling codes on the multi-metering relay set associated with the individual junction. In these circumstances a common multi-metering relay set is provided which can be switched as required to any outgoing junction in order to cater for the additional codes.

Standard Units. A No. 13 type exchange is built up of the required number of three basic standard units:

Line unit	Code No. 13A
Junction unit	Code No. 13B
Cross-connexion frames and miscellaneous apparatus unit.	Code No. 13C

A 200-line exchange (when equipped to the maximum capacity) requires one C unit, four A units, and a number of B units depending upon the junction requirements. A No. 13X exchange requires two C units, a maximum of eight A units, and a number of B units for junction equipment.

Each unit is enclosed in a steel cabinet which consists of an inner and an outer case with a $\frac{1}{4}$ in. cavity between them. Battens are fitted within the cavities to reinforce the structure. The approximate weights and dimensions of the units are:

Unit	Height ft	Height in.	Depth ft	Depth in.	Width ft	Width in.	Weight lb
A	8	3	1	$2\frac{1}{2}$	2	7	565
B	8	3	1	$2\frac{1}{2}$	2	7	322
C	8	3	1	9	2	8	662

The apparatus rack of each unit is built up of mild steel angles and is secured to the cabinet at the sides, top, and bottom. The apparatus racks of the A and B units are of the single-sided type, i.e. with apparatus mounted at the front, and the connexion strips, cabling, wiring, etc., at the rear.

Each unit is provided with two doors on the apparatus side and three doors on the wiring side (except the C unit which has doors at the end in order to provide access to the M.D.F.). Like the units, these doors are of cavity construction and are clamped in position by simple wing nut fastenings. Rubber gaskets and a fabric-covered rubber cord ensure that the doors fit tightly on all edges when the wing nuts are tightened.

Unit No. 13A. This unit accommodates the subscribers' line relays, the linefinders, their associated allotters and control circuits, the group and final selectors, and the subscribers' and traffic meters. The equipment is mounted on seven shelves as shown in Fig. 435.

Shelf A is equipped for 30 subscribers' calling equipments, a plate of miscellaneous relays, and the 2 allotter uniselectors. There is capacity for a further 20 subscribers' calling equipments, i.e. to bring the total equipment up to 50 circuits.

Shelf B is wired for the 2 linefinder control relay sets and for 3 linefinder mechanisms.

Shelf C provides accommodation for a further 5 linefinder mechanisms.

Shelf D is equipped for 30 subscribers' meters and for a linefinder overflow meter. There is capacity for increasing the equipment to 50 subscribers' meters, and a total of 11 overflow meters.

Shelf E is wired for 4 group selectors.

Shelf F is similarly wired for a further 4 group selectors. The unit fuse panel is located on the left of shelves E and F.

Shelf G provides a capacity for 5 final selectors.

The linefinders, group selectors, and final selectors are not normally supplied with the unit but are added as required to suit the traffic requirements of each individual exchange. Various test jacks, routine test keys and lamps are fitted to the right of shelves B and C.

Unit No. 13B. This unit accommodates the various relay groups, uniselectors, etc., required for the termination of junction circuits. The junction requirements of a U.A.X. 13 differ widely, and it is usual, therefore, to supply unequipped B units so that the relay groups can be added as required. Most of the junction apparatus is "strip mounted," and the apparatus rack is provided with universal drillings which cater for a maximum of 29 single horizontal mounting plates or their equivalents. Some junction units require only one single mounting plate, but other units may require two or three such horizontal plates which are bolted together to make complete assemblies. The wiring from each relay group is brought out to a connexion strip which provides a terminating point for the inter-unit cables.

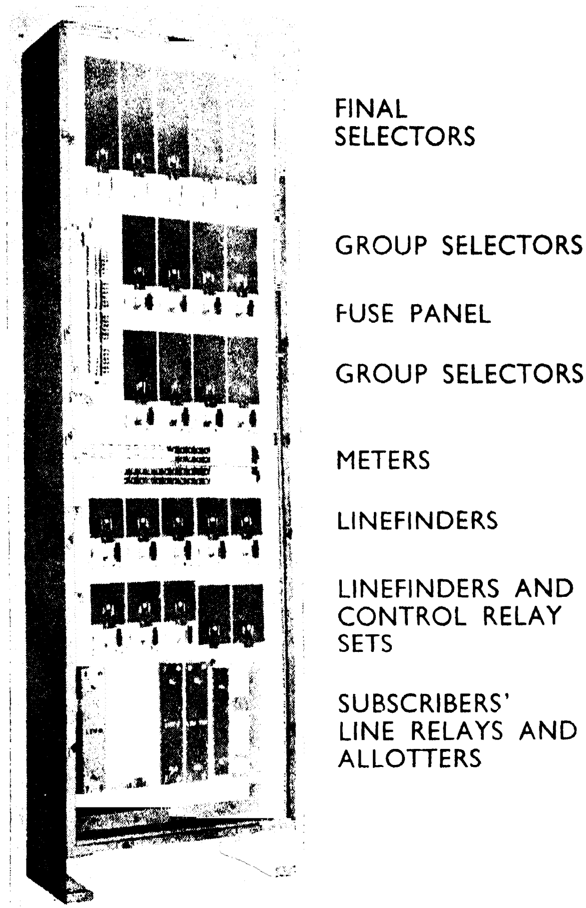


FIG. 435. UNIT NO. 13A
(As seen from front with covers removed)

Fig. 436 shows a typical arrangement of equipment on a B unit. It will be noted that the uniselectors (e.g. junction hunters) and some of the relay groups are mounted vertically in suitable panels, whilst the common multi-metering equipment is in the form of a jacked-in relay set.

Unit No. 13C. This unit (Fig. 437) accommodates the M.D.F., the I.D.F., an alarm lamp panel, line testing equipment, and the relay sets required for ringing, tones, time, and meter pulses. The line

side of the M.D.F. is accessible from the rear of the unit and has a maximum capacity for 320 circuits. The exchange (or protector) side of the M.D.F. is accessible from the front of the unit and has a capacity for 240 circuits. Jumpering not normally glow, but can be brought into use when required by the depression of a press button on the side of the unit. The multiple side of the I.D.F. is placed at the front of the unit above the testing equipment, and the local side of this same

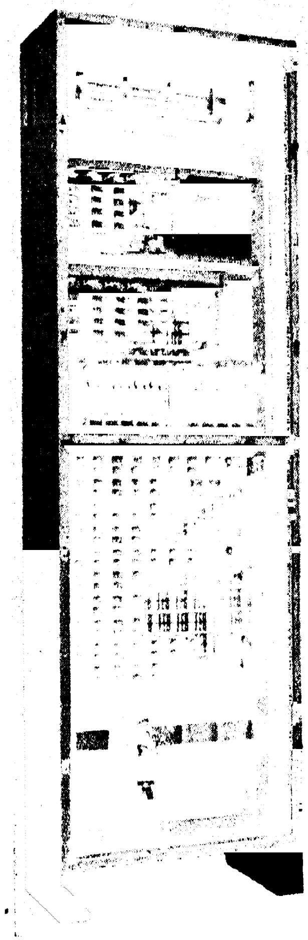


FIG. 436. UNIT NO. 13B
(As seen from front with covers removed)

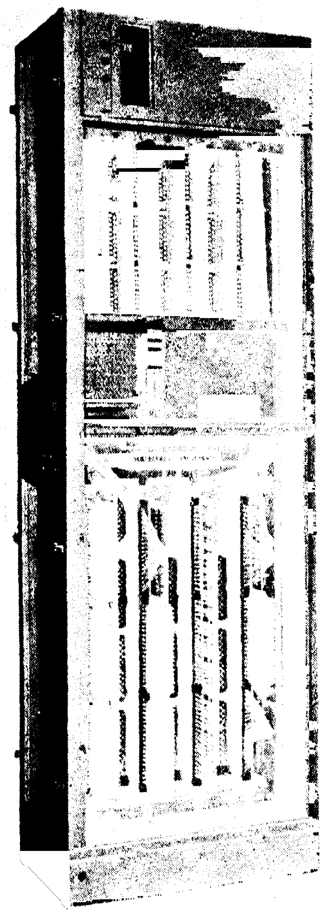


FIG. 437. UNIT NO. 13C
(As seen from front with covers removed)

arrangements between the two sides of the frame follow standard practice.

The space immediately above the protectors is occupied by a test panel which includes the normal facilities for line testing, a strip of jacks which can be used for connecting N.U. tone to lines temporarily out of service, and an alarm localizing lamp panel. This lamp panel contains a group of seven lamps which are mounted in such a position that the lamps (and their designations) are clearly visible through a window when the doors of the unit are in place. The alarm lamps do

frame appears in a similar position at the rear of the unit. Five verticals are provided on each side of the I.D.F., and the connexion strips are arranged to give a straight jumpering scheme as far as is practicable. The connexion strips above the local side of the I.D.F. are associated with the supply of tones, pulses, ringing, positive battery, etc. The relay sets which contain the common equipment for ringing, meter pulses, time pulses, tones, etc., and various alarm fuses are mounted at the rear of the unit behind the test panel.

Lay-out and Cabling. In the past, most U.A.X.s 13 have been installed in standard buildings of the "B" type. This building has internal dimensions of 19 ft × 10 ft 6 in. and provides accommodation for four A units and up to five B units in addition to the C unit, and the power plant. A typical lay-out of a 200-line No. 13 exchange in a B type building is shown in Fig. 438. In future the B1 type of building (Fig. 439) will be standard for U.A.X.s 13. This building is somewhat larger than the B type, with internal dimensions of 21 ft × 14 ft. The extra width of the B1 type building permits the units to be arranged in three rows with a maximum capacity of some 15 units in all. This same building will, in some circumstances, cater for an extension of the equipment beyond 200 lines, but a full U.A.X. 13X will usually require an extended building.

The external cables enter the building through ducts in the end wall and are led to the C unit through a wood covered cable trench in the floor. The required number of A units is installed alongside the M.D.F. unit whilst the B units are arranged as separate suites with an overhead cable run to the C unit. The inter-suite cable run is in the form of a sealed cable trough of sheet metal which, like the units themselves, is of cavity construction. Arrangements are made for sealing all cable holes between units. The battery is accommodated on a wood or concrete battery rack which runs along one of the longer walls of the building, whilst the power panel, with its rectifiers, etc., is located as near as possible to the battery rack.

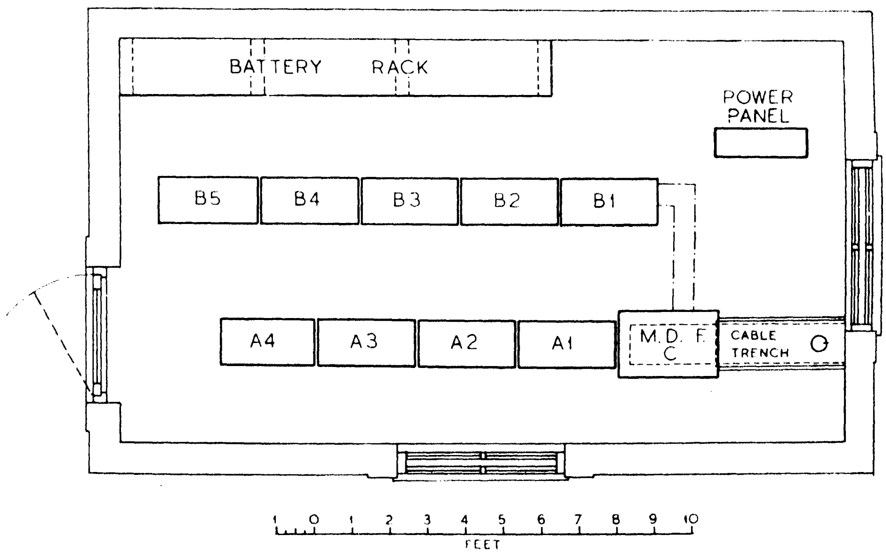


FIG. 438. LAY-OUT OF 200-LINE EXCHANGE IN B TYPE BUILDING

The subscribers' line relays (and meters) are directly wired to the banks of the linefinders on each A unit. The lines are then cabled to the local side of the I.D.F. The group selectors are con-

FIG. 439. GENERAL VIEW OF B1 TYPE BUILDING

nected locally to the appropriate linefinders on each unit. Levels 2 and 3 are cabled direct to the final selectors on the unit, whilst levels 4 to 0 are multipled to the group selector banks of all A units and are then cabled as required to the local side of the I.D.F. where they can be cross-jumpered to junction relay groups. The final selector banks are multipled to each pair of A units, and then cabled to the multiple side of the I.D.F. The control relay sets of each A unit are also wired to the I.D.F. multiple, so that the necessary connexions can be made from the junction terminations.

Linefinder and Associated Circuits. The linefinder circuit of a U.A.X. 13 is given in Fig. 440. The complete circuit contains three main parts, viz:

Subscriber's line circuit.
The linefinder circuit.
The control relay set.

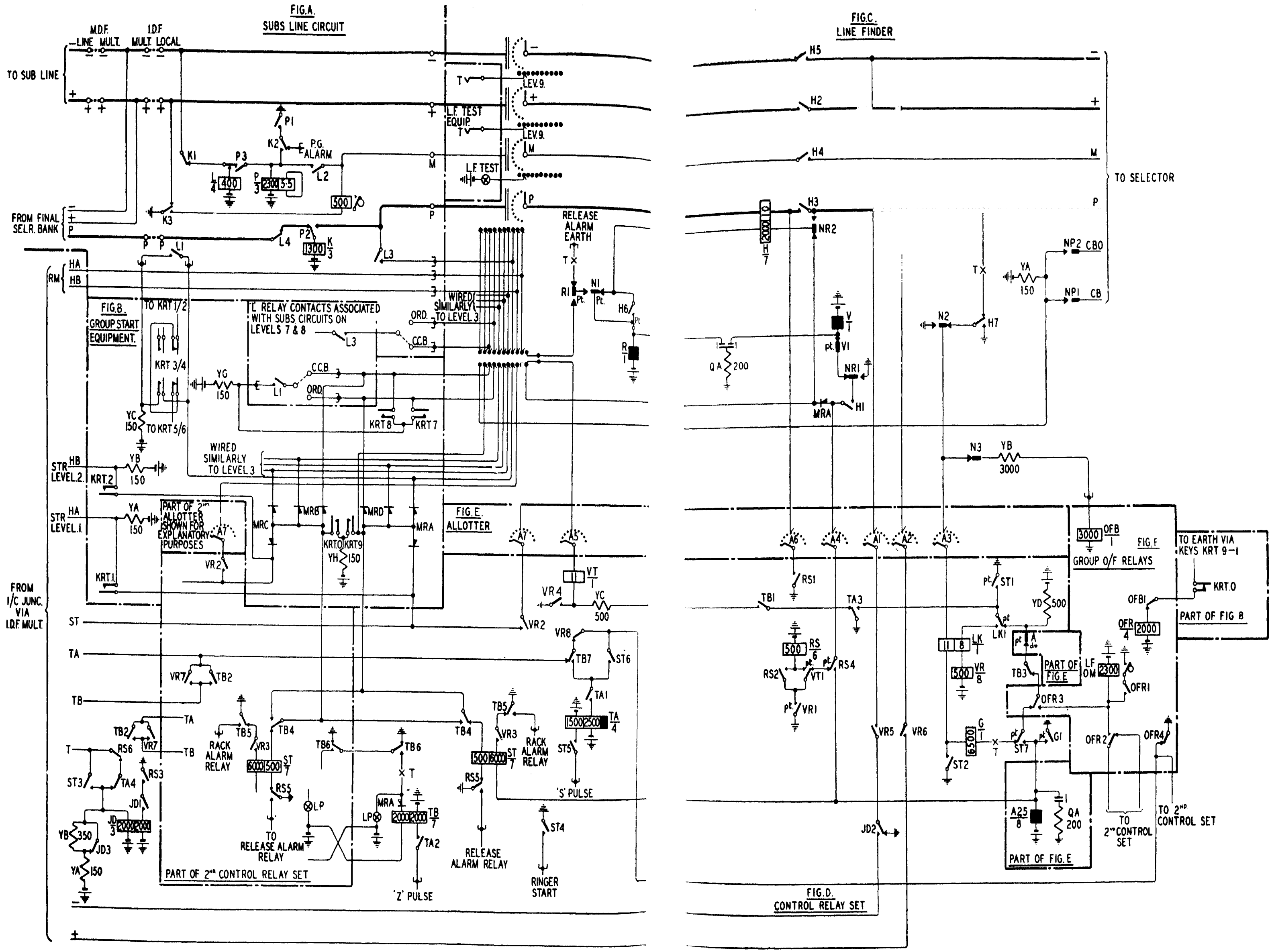


Fig. 440. Complete Linefinder and its Associated Circuits

In addition there is a group start circuit which contains various keys, etc., for routine testing. Part of the second control circuit is also shown to illustrate the changeover arrangements under fault conditions. The detailed operation of the various component parts will be considered separately in the following paragraphs, but it is desirable at this stage to summarize the main facilities provided by the equipment. Provision is made for:

(1) Pre-selection of a free linefinder by the control relay set and allotter.

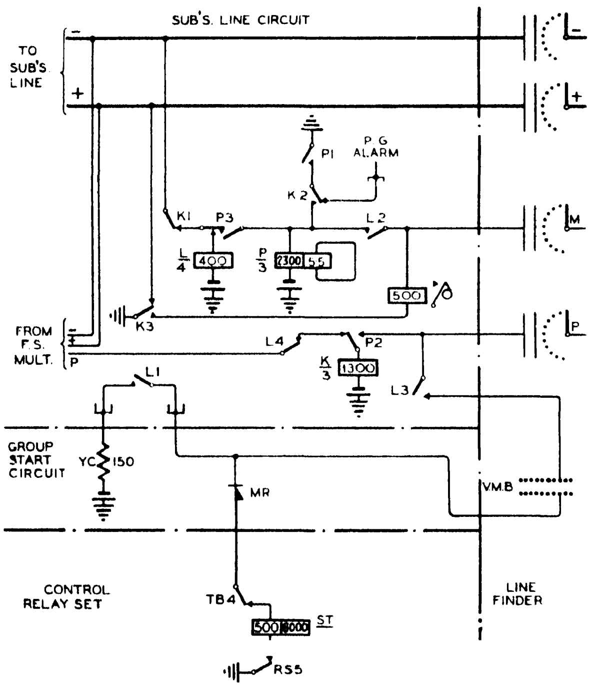


Fig. 441. Subscriber's Line Circuit

(2) Finding a calling line and extending it to a free group selector.

(3) The preparation of the group selector circuit for the receipt of impulses whilst the linefinder is searching for a calling line.

(4) The extension of a discriminating signal to the group selector when the call is from a coin-box subscriber.

(5) Alternative access to a second control set from incoming junctions should the primary control set be engaged.

(6) An advance dialling path for incoming junctions through the control set so that impulsing can proceed prior to the seizure of the calling junction by the linefinder.

(7) An extension of a discriminating signal over the *M*-wire to the group selector on incoming junction calls.

(8) Congestion metering when all linefinders are engaged.

(9) Lock-out of faulty control set, and automatic diversion of calls to remaining control set.

(10) Linefinder lock-out on failure of vertical stepping.

(11) A release alarm should the linefinder fail to restore.

(12) The prevention of allotter search when all linefinders are engaged.

(13) Semi-automatic routining of the equipment.

Subscriber's Line Circuit. Fig. 441 shows the connexions of the subscriber's line relays. When a subscriber lifts his receiver, the completion of a d.c. loop provides a circuit for relay *L* which operates to the earth at the *K3* contact. ***L1*** extends a 150 Ω battery from the group start circuit to mark the appropriate level on the vertical marking bank of the linefinder, and also to operate relay *ST* in the control relay set. ***L3*** connects the second side of the vertical marking bank to the *P* bank contact of the calling line in readiness for marking the rotary position of the calling subscriber on the selected level of the linefinder bank. ***L4*** disconnects the incoming *P*-wire from the final selector multiple to engage the line (the final selector is battery testing).

The operation of the start relay in the control relay set causes the linefinder to step vertically until battery is encountered on the vertical marking bank and then to hunt over that level until the wipers reach the particular marked contact of the *P* bank. The switching relay of the linefinder operates and extends the caller to the group selector. Earth is now applied back on the *M*-wire to operate relay *P* in the line circuit. ***P2*** operates relay *K* by applying it to the earthed *P*-wire. All bridging apparatus is now removed from the speaking pair, which is extended to the group selector in readiness for impulsing. Relay *K* is also under the control of the earth on the *P*-wire, and ***K2*** in turn holds relay *P* over a local circuit. This condition persists until the earth is removed from the *P*-wire at the end of the call when relays *K* and *P* release to restore the *L* relay to the line.

The group selector circuit is arranged to provide forced release conditions if the selector is seized but not stepped within a reasonable period (e.g. under P.G. conditions). Forced release is also applied under called-subscriber-held conditions and where a subscriber holds on to a spare dialling code. The forced release consists of the withdrawal of the earth from the *P*-wire, and this in turn

allows relay *K* in the subscriber's line circuit to restore. *K*3 re-applies earth to the + line, whilst *K*1 completes a circuit for the holding of relay *P*. *K*2 disconnects the normal holding circuit of relay *P*, but the latter relay holds via ***P*3**, *K*1, and the subscriber's loop to the earth at *K*3. ***P*1** extends an earth to the P.G. alarm circuit,

Search for and Switching to Calling Subscriber's Line. The allotter normally rests on an outlet to a free linefinder. The conditions existing when the start condition is extended to the control relay set are shown schematically in Fig. **442.** The start battery operates relay *ST* in the control relay set, and ***ST*2** completes a circuit for relay

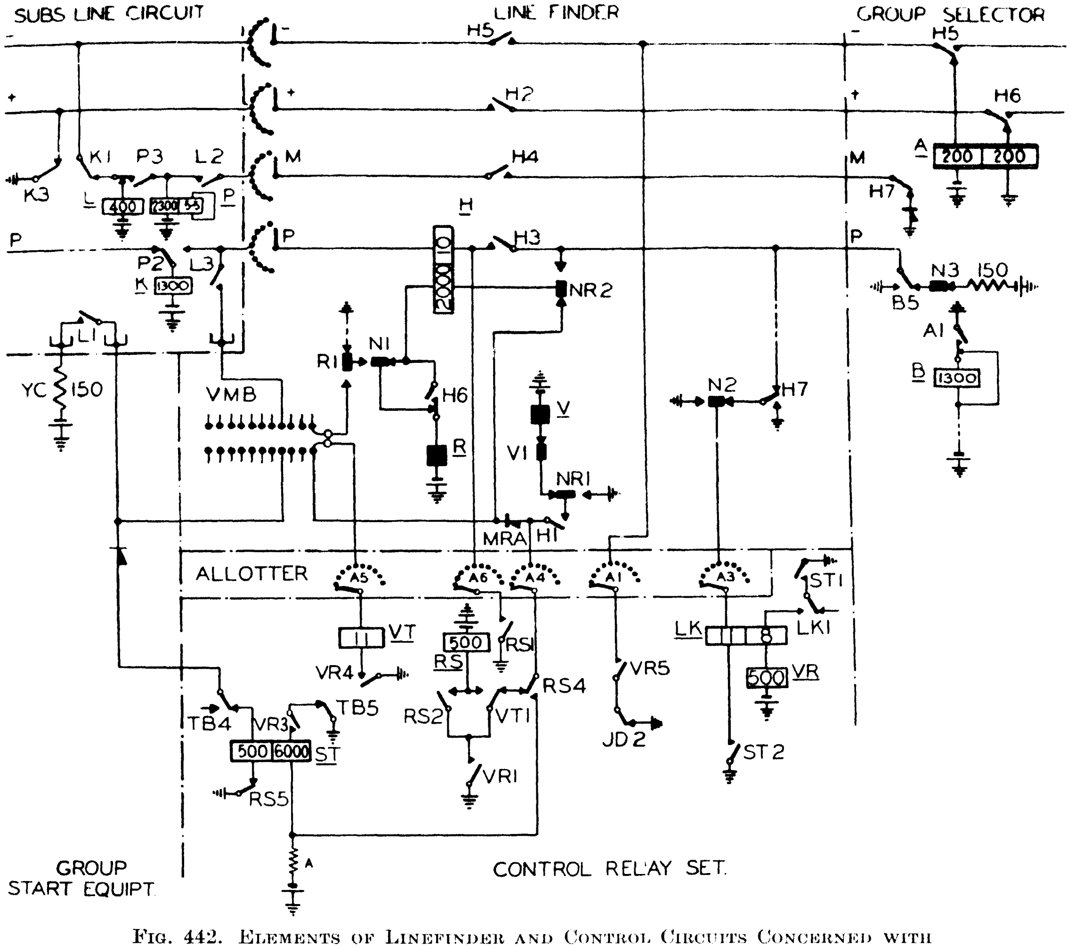


FIG. 442. ELEMENTS OF LINEFINDER AND CONTROL CIRCUITS CONCERNED WITH SEARCH FOR AND SEIZURE OF A CALLING SUBSCRIBER'S LINE

whilst ***P*2** maintains the engaged condition on the final selector multiple.

On incoming calls, relay *K* operates to the earth extended forward from the final selector on the *P*-wire. ***K*1** and ***K*3** remove the *L* relay from the speaking pair as before, and the caller is extended to the subscriber's line.

Rectifier *MR* is inserted in the start relay circuit to prevent the start condition from being fed back via the start relay common to the other levels of the vertical marking bank.

LK to the battery on the *P*-wire from the free group selector. ***ST*1** and ***LK*1** provide a holding circuit for *LK* and operate *VR*. ***VR*5** now applies an earth to the − line to pre-operate the *A* relay of the group selector on one winding. The operation of relay *A* in the group selector in turn operates *B*, and ***B*5** returns a guarding earth on the *P*-wire.

It has been seen that the ***L*1** contact of the subscriber's line circuit in addition to operating relay *ST* also marks the vertical marking bank

contact corresponding to the level in which the calling subscriber is located. In Fig. 442 the calling circuit is assumed to be connected to level 3. The operation of ***VR*1** provides an operating circuit

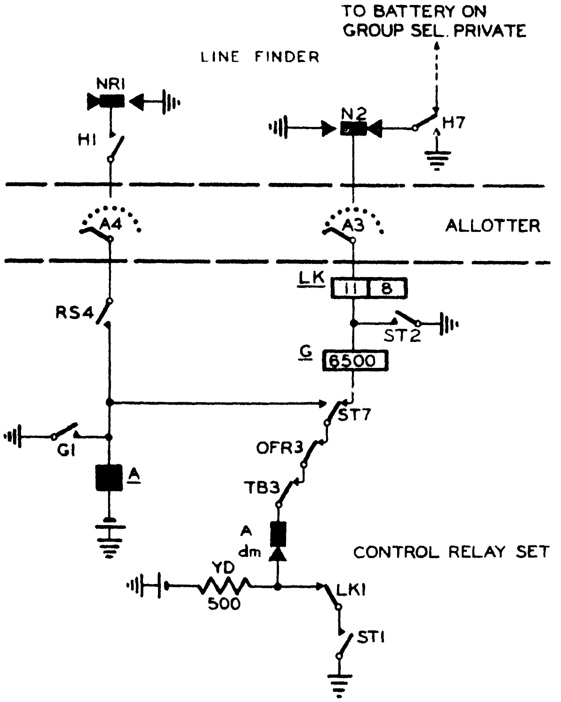


Fig. 443. Stepping Circuit of Allotter

for the linefinder *H* relay to the battery at the rotary magnet. ***VR*4** completes the vertical testing circuit by connecting relay *VT* to the *VMB* wiper. The vertical magnet self-drive circuit is completed at ***H*1** (to the earth at ***VR*1**), and vertical hunting takes place until the *VMB* wiper reaches the marked contact. The marking battery is now extended via arc 5 of the allotter to operate relay *VT*. ***VT*1** disconnects the vertical stepping circuit and also releases relay *H*.

The operation of ***VT*1** also completes a circuit for relay *RS* which locks via its own contact to the ***VR*1** earth. On the release of contact *H*6, the rotary magnet is energized via ***N*1** and its own interrupter springs *R*1. Rotary hunting under self-drive conditions now takes place, and at each operation of the ***R*1** contacts, the rotary magnet is extended to the second wiper of the vertical marking bank. When the *P* bank contact of the calling subscriber is reached, the *R* magnet battery is extended via the vertical marking bank, contact **L3** and the *P* bank to the 10 Ω coil of the *H* relay and thence to earth at ***RS*1**. The *H* relay now operates and at ***H*6** disconnects the rotary drive circuit. At the same time ***H*6** provides a holding circuit for relay *H* via ***NR*2** to the earth on the *P*-wire.

The ***H*2** and ***H*5** contacts extend the + and − wires to the *A* relay of the group selector, whilst ***H*4** operates the *P* relay in the subscriber's line circuit. ***P*2** in turn operates the *K* relay to the earth on the *P*-wire. ***K*1** and ***K*3** remove the bridging apparatus, whilst ***P*1** and ***K*2** (Fig. 441) hold relay *P*.

The release of the *L*1 contact in the subscriber's line circuit removes the marking battery from the *VT* relay which now restores to normal. ***H*1** applies the earth from ***NR*1** to the battery side of the *ST* relay holding coil, and this relay also releases. *ST* releases *LK* and *VR*, whilst *VR* in turn releases *RS*.

Stepping of Allotter. The allotter switch stepping circuit is shown in Fig. 443. When the *H* relay switches upon the finding of the calling circuit, the earth at ***NR*1** is extended via arc 4 of the allotter to energize the allotter drive magnet (*A*). Consequently, upon the release of *RS*4, the magnet

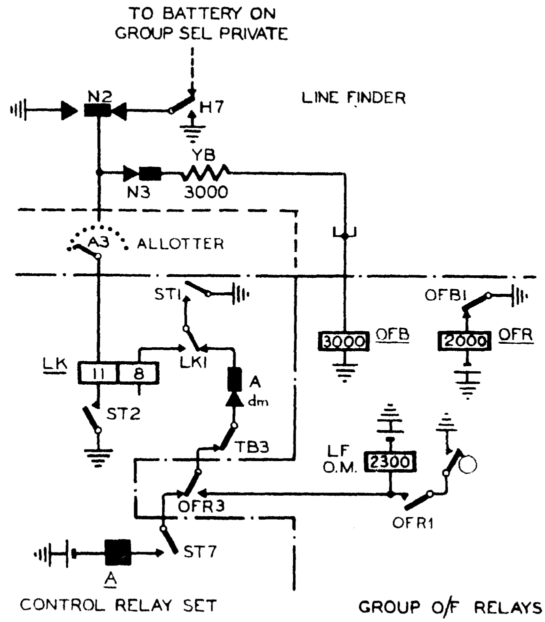


Fig. 444. Group Overflow Circuit

is de-energized and the allotter wipers step to the next contact.

A battery condition on arc 3 of the allotter (from the group selector *P*-wire) indicates that the allotter has been stepped to a linefinder which is associated with a free group selector. If, on the

other hand, the outlet to which the allotter wipers step is marked with an earth, it is an indication that the linefinder is busy, and the allotter must step to the next outlet. Under these conditions relay *G* operates from the 500 Ω battery at *YD* to the earth at ***N2*** or ***H7***. ***G1*** energizes the allotter driving magnet and the ***Adm*** contacts open to release *G*. This interaction between relay *G* and the driving magnet continues until the wipers reach a free outlet.

Should another calling subscriber seize the control relay set during the period that the allotter is stepping over busy outlets, the operation of ***ST2*** applies full earth to relay *LK*. A self-drive circuit for the allotter is now completed via ***ST7*** to the earth at ***ST1***. When the wipers reach a free outlet, the presence of a battery condition on the *P*-wire of the group selector allows *LK* to operate which, at ***LK1***, cuts the drive circuit. The call now proceeds as described previously. It should be noted that the allotter will drive as described above over any outlets which are disconnected at the *A3* bank contact.

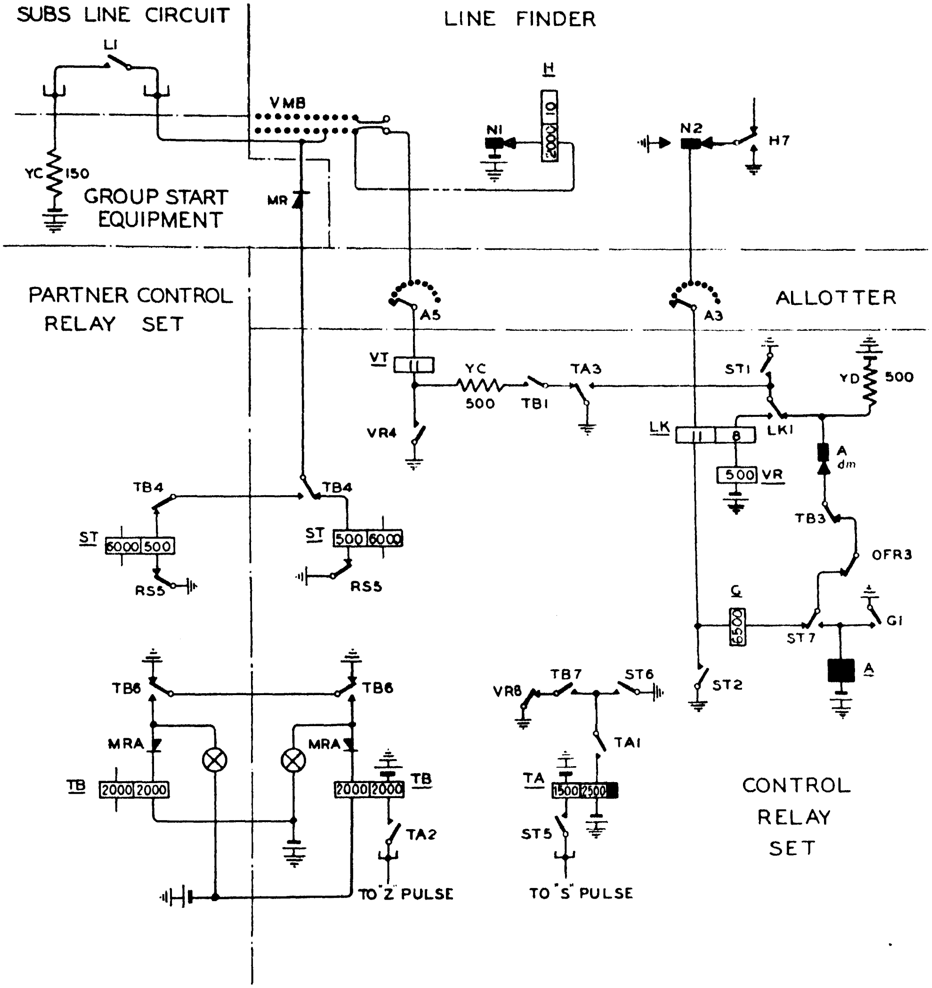


Fig. 445. Switching to Second Control Set under Fault Conditions

Group Overflow. The off-normal springs (*N*3) of each linefinder are wired via a 3000 Ω resistor to a common relay *OFB* (Fig. 444). Thus, relay *OFB* is operated (from the battery potential on the *P*-wire) whenever a free linefinder exists. When the last free linefinder is taken into use, relay *OFB* releases, and at *OFB*1 operates relay *OFR*. ***OFR3*** disconnects the allotter drive circuit. Should a subscriber call when this condition exists, the operation of ***ST1*** extends an earth to the overflow meter, which operates and locks via the ***OFR1*** contact.

When a linefinder becomes free, *OFB* re-operates and *OFR* releases. *OFR*1 allows the meter to restore and, if the subscriber is still calling, *OFR*3 completes the drive circuit for the allotter. The 3000 Ω resistor (*YB*) in each linefinder circuit prevents the release of relay *OFB* should the *P*-wire of any linefinder (which is normal) be connected to earth (e.g. if the linefinder or the associated group selector is artificially busied by the application of an earth on the *P*-wire).

Fault Conditions. When a control relay set is seized, ***ST5*** extends relay *TA* to the *S* pulse of the common equipment (Fig. 445). On th first

S pulse, *TA* operates and holds to the earth at ***ST6***. Normally, the control set establishes the call and is released before the application of the *Z* pulse, but if there is a fault (e.g. if the allotter fails to step), the *Z* pulse operates relay *TB* before

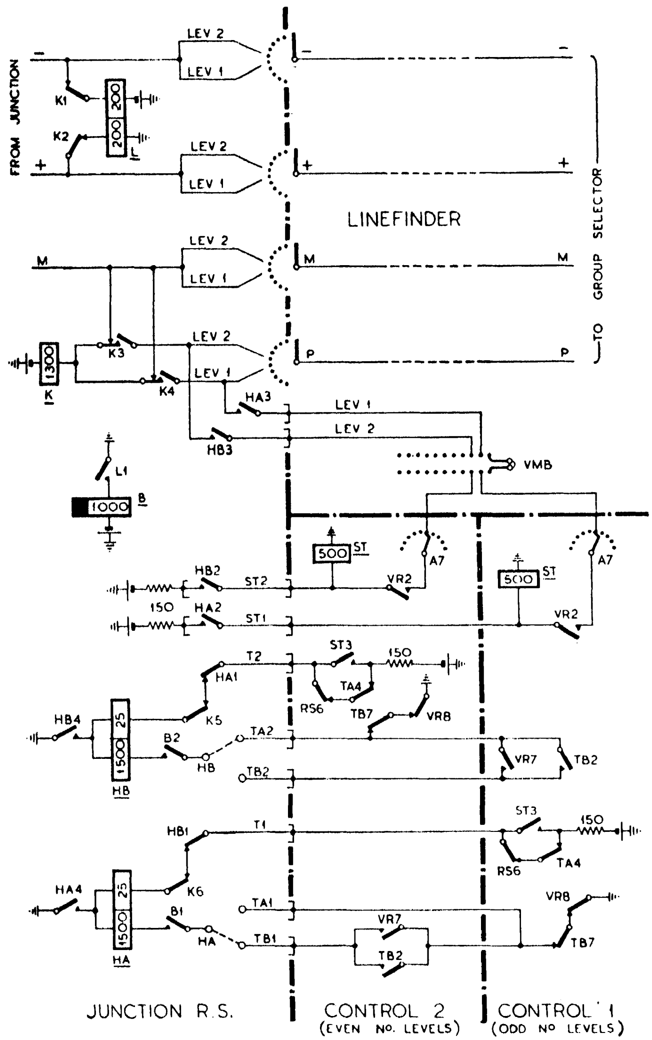


FIG. 446. DUAL SWITCHING FACILITY ON INCOMING JUNCTIONS

the control set is released. ***TB3*** disconnects the allotter stepping circuit, whilst ***TB4*** changes over the start wire of the calling circuit to the *ST* relay of the partner control relay set. The *ST* relay of the fault control set now restores to release the *TA* relay. ***TB6*** provides a holding circuit for the *TB* relay via its second winding to the earth at the *TB6* contact of the partner relay set, thereby locking the faulty control set out of service and lighting the fault lamp.

If the control set should seize a faulty linefinder, the *S* and *Z* pulses operate the *TA* and *TB* relays as already described and the calling circuit is switched to the partner relay set. When relay *ST* releases, an earth is extended from *TA3*, via the *VT* relay, arc 5 of the allotter, the vertical marking bank of the faulty linefinder to the *H* relay in the latter. *H* operates and at ***H7*** places a busying earth on arc 3 of the allotter bank. Both the control set and the linefinder now remain locked out of service until the fault is dealt with. The make side of the ***TA3*** contact maintains the *VR* relay during the operation of the *TB* relay by the *Z* pulse. This prevents the locking of relay *TA* by ***TB7***.

If an earth fault develops on the battery common of the control set, battery from the partner control set fuse is extended via relay *TB*, rectifier *MRA*, and the alarm lamp to the earth fault. The consequent operation of relay *TB* switches the start wire to the partner relay set. The rectifiers prevent the operation of the *TB* relay in series with the lamp should an earth fault cause the fuse in the partner allotter to operate. This condition would otherwise cause interaction between the two *TB* relays.

The circuit arrangements provide alarm conditions when any of the above faults exists.

Switching to Alternative Control Set on Incoming Junctions. It has been stated that the incoming junctions to a U.A.X. 13 are distributed amongst the various linefinder groups where they appear on levels 1 and 2 of the linefinder banks. The speaking conductors and the meter wires are commoned to both levels, but the *P*-wires of level 1 and level 2 are taken out separately so that the marking condition can be placed either on level 1 or on level 2 as required. One of the two control sets serves level 1, whilst the remaining control set serves level 2 of the linefinder group. In order to distribute the load between the two control sets as evenly as possible, the incoming junctions are arranged so that the marking condition for approximately half the junctions appears on level 1, whilst the normal marking condition for the other half of the junctions appears on level 2. Arrangements are made, however, so that if the first choice control set is already engaged on another call, the marking condition can be switched to the alternate level so

that the second control set can be used on an incoming junction call.

Fig. 446 shows the main circuit features of the switching relays in the junction termination which provide for the transfer of the marking condition from the primary to the secondary level. For purposes of illustration it has been assumed that the junction has a primary calling position on level 2 and is normally served by control set No. 2. If this control set is engaged, however, the marking condition is automatically transferred to level 1, so that the call can be handled by control set No. 1.

Relay *L* operates to the calling condition on the junction, and at ***L*1** energizes relay *B*. Contact ***B*1** now extends one side of relay *HA* to the *TB*-lead of control set No. 1, whilst contact ***B*2** extends the *HB* relay to the *TA*-lead of control set No. 2. If control set No. 2 is disengaged, relays *VR* and *RS* are normal so that earth is extended via *VR*8, *TB*7, ***B*2**, both coils of relay *HB* in series, *K*5, *HA*1, *RS*6, and *TA*4 to the 150 Ω battery. *HB* operates over this circuit. ***HB*4** applies the low resistance winding of *HB* to the *T*2-lead, thereby providing a holding circuit for *HB* and engaging control set No. 2 against any other calling junction. ***HB*1** disconnects a possible operate circuit for relay *HA*, whilst ***HB*2** prepares a battery marking condition to level 2 of the linefinder vertical marking bank. ***HB*3** connects the other side of this bank to the appropriate *P* bank contact on level 2.

The operation of ***HB*2** also operates relay *ST* in control set No. 2. ***ST*3** provides an alternative holding circuit for relay *HB* in readiness for the operation of ***RS*6** when the linefinder reaches the marked level. Other contacts of the *ST* relay start the linefinder search and, when the calling junction is found, the application of earth from the group selector on the *M*-wire operates relay *K*. *K* now holds via ***K*3** to the earth on the *P*-wire, and at ***K*5** disconnects the holding circuit for *HB*. *HB*2 now releases *ST*, and the control set is available for use on further calls.

If an incoming junction call occurs whilst control set No. 2 is in use on another call, relay *VR* of this control set will be operated. (It will be recalled that *VR* operates when the allotter seizes a free linefinder.) ***VR*8** prevents the operation of relay *HB*, but ***VR*7** provides an alternative operate circuit for relay *HA* if control set No. 1 is at this time disengaged. ***HA*2** marks level 1 of the linefinder vertical marking bank, whilst ***HA*3** marks the appropriate rotary position on level 1 of the linefinder *P* bank. ***HA*1** prevents the operation of relay *HB*. ***HA*2** also operates the start relay of control set No. 1, and the linefinder commences to search for the calling line on level 1 of the bank. When the line is seized, relay *K* operates as before, and at ***K*6** breaks the holding circuit for relay *HA* and thereby releases the control set for use on a succeeding call.

It will be noted that contacts of relays *TA* and *TB* are inserted in the operate circuits of the switching relays. Thus, if control set No. 2 is locked out due to fault conditions, it is impossible for relay *HB* to switch due to the presence of contact ***TB*7**. At the same time, however, contact ***TB*2** extends relay *HA* to control set No. 1 so that, if the latter is disengaged, the call can proceed via level 1.

It is important that a control set should not be seized by an incoming junction until it has fully restored from a previous call. It has been seen that when a linefinder switches to a calling line, the release of relay *ST* breaks the circuit for *VR*, and *VR* in turn releases *RS*. It is therefore important to include a contact of *RS* in the operating circuit of the switching relays. Similarly, relay *TA* may be operated by the *S* pulse on a preceding call, and as this relay is slow-to-release, contact ***TA*4** is inserted to prevent seizure of the control set until the *TA* relay is normal.

Any incoming junction circuit can be given a primary calling position on level 1 or level 2 as desired by the connexions of terminals *HA* and *HB*. In Fig. 446, for example, the junction could be made to have a primary appearance on level 1 by connecting terminal *HA* to terminal *TA*1 and terminal *HB* to terminal *TB*2. This would make relay *HA* the primary switching relay in conjunction with control set No. 1, and *HB* would only operate to seize control set No. 2 in the event of engaged or fault conditions on control set No. 1.

Pre-dialling Path for Incoming Junctions. We have seen earlier that it is of some importance that incoming junctions should be associated with a group selector in the minimum time in order to avoid possible mutilation of the first impulse train. (This is, of course, necessary because calls on incoming junctions may be routed from selector levels at the distant exchange, and there may be very little left of the interdigital pause by the time the call is extended to the U.A.X.)

The seizure time at the U.A.X. is minimized firstly by locating the junctions on the first two levels of the linefinder bank, and also by the primary and secondary switching scheme described in the previous paragraph. A further safeguard is introduced by providing a pre-dialling

path through the control relay set to the group selector until such time as the linefinder seizes and switches to the calling junction.

Fig. 447 shows the basic circuit arrangements. To avoid unnecessary complexity, only one of the switching relays (*HB*) of the junction relay set is shown. The calling condition on the junction operates relay *L*, and *L* in turn operates *BC*. A contact of *BC* now extends the *HB* relay to the *TB*-lead of the control relay set and, if the latter is disengaged, a circuit is provided for *HB* from the battery at *YA* via *TA*4, *RS*6, contacts of relays *HA* and *K*, both coils of relay *HB* to the earth at *VR*8. Relay *HB* operates over this circuit and holds on its 25 Ω coil. This reduction in the resistance of the circuit now allows relay *JD* in the control relay set to operate. ***JD*2** prepares for the extension of the junction loop to the group selector so that impulsing can proceed, whilst the control relay set is directing the linefinder to the appropriate position.

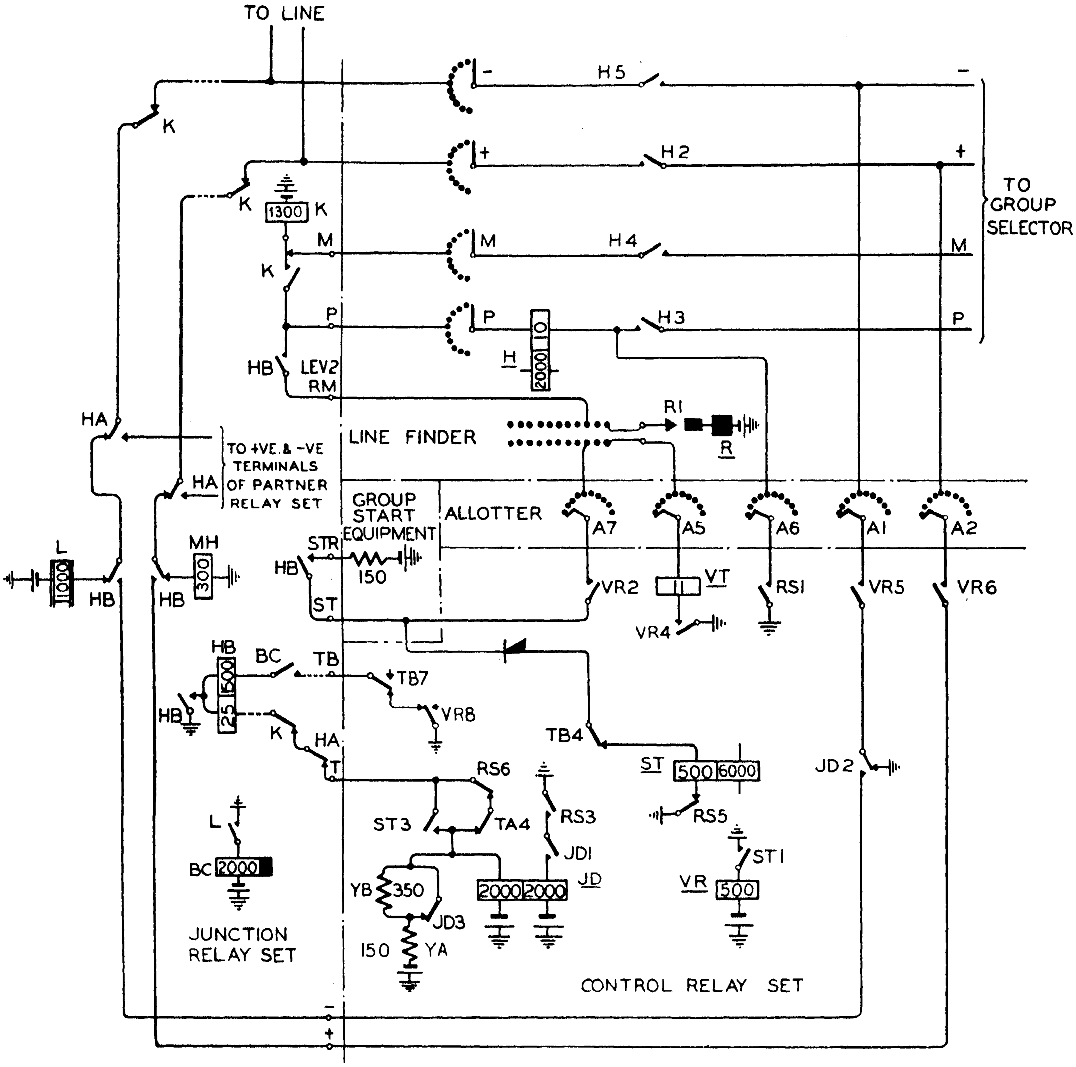


FIG. 447. PRE-DIALLING PATH THROUGH CONTROL RELAY SET

A contact of the *HB* relay applies the 150 Ω battery of the group start circuit to operate relay *ST*, and ***ST*1** in turn operates relay *VR*. ***VR*2** now extends the marking battery to the second level of the linefinder vertical marking bank,

whilst ***VR*4** prepares the vertical test circuit. ***VR*5** and ***VR*6** complete the pre-dialling path. In due course the wipers reach the marked (second) level when battery from the *R* magnet is extended via the *RM*-lead to the *P* bank contact on level 2 corresponding with the calling junction. The wipers are now stepped round the bank until the marked contact is reached, when relay *K* operates to the earth on the *M*-wire. *K* now disconnects the *HB* relay from the control relay set so that

(*b*) Forced release conditions are applied after a delay period if a selector is held

(i) to a permanent loop,
(ii) on N.U. tone,
(iii) on busy tone.

(*c*) Discriminating signals are passed forward to the junction relay set if the selector is taken into use by a coin-box subscriber or an incoming junction.

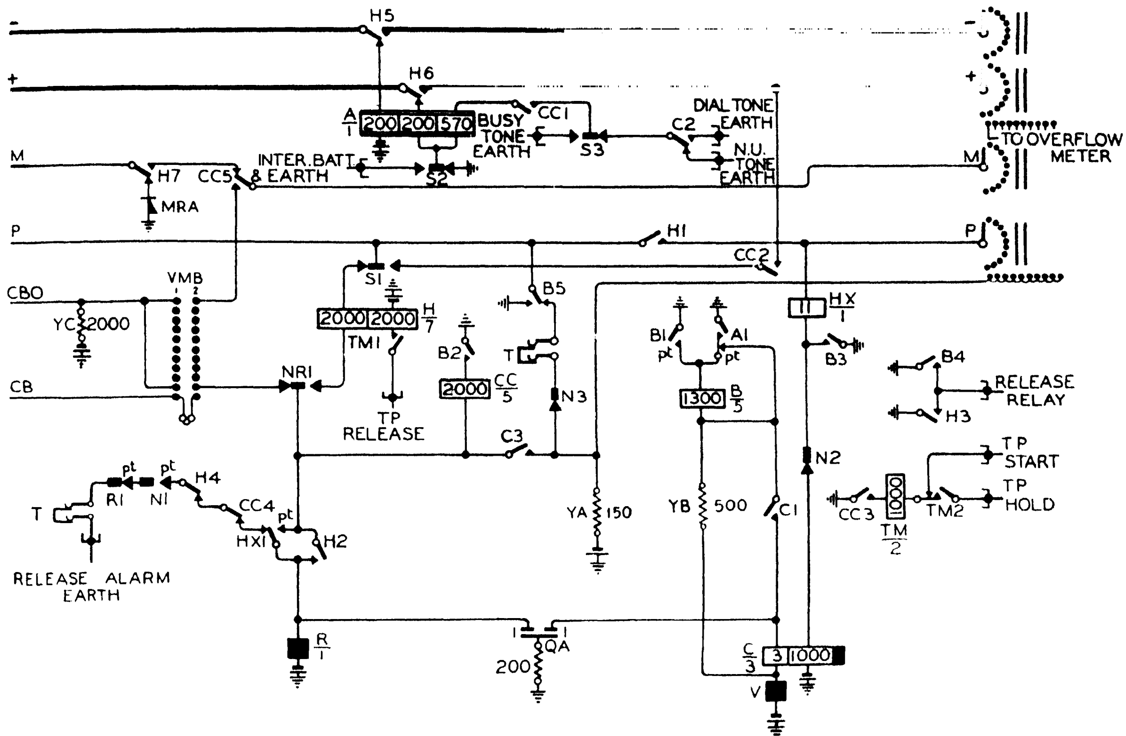


FIG. 448. U.A.X. 13 GROUP SELECTOR

relay *JD* releases. An alternative impulsing path is by this time established via the − and + wipers of the linefinder and contacts ***H*2** and ***H*5**. It will be noted that the alternative impulsing path is established before the primary path is disconnected. Hence the changeover can take place even in the middle of an impulse train without the danger of mutilated impulses.

Group Selector. The subscriber's loop is extended by the linefinder to a group selector of the 100-outlet type. In addition to the normal facilities provided by a group selector, the circuit (Fig. 448) provides the following special facilities:

(*a*) N.U. tone is transmitted to a coin-box subscriber should he dial a "barred" level.

Battery testing into the group selector is used, and the circuit arrangements are such that the selector is automatically busied if it fails to release due to a mechanical fault or if the battery supply to the selector is disconnected due to a blown fuse or other cause.

The energization of relay *A* to the calling subscriber's loop operates relay *B*, and ***B*3** in turn operates *C*. ***B*5** provides the earth to hold relay *H* in the linefinder and relay *K* in the subscriber's line circuit. ***C*3** operates relay *CC*, and ***CC*1** completes the circuit for dial tone.

The impulses from the subscriber's dial step the selector to the required level and, at the end of the vertical impulse train, relays *C* and *CC*

release. The restoration of $CC4$ completes the rotary drive circuit and the wipers step round the bank until they encounter a free outlet. Relay HX operates to the battery on the P-wire, and at ***HX*1** disconnects the rotary drive circuit. A circuit is now completed for relay H which operates from the earth on the P-wire to the battery at the rotary magnet. Relay CC also re-operates from the same battery supply. Contacts of relay H (***H*1**, ***H*5**, and ***H*6**) extend the P, $-$ and $+$ wires to the final selector or junction relay set according to the digit dialled. ***H*1** also short-circuits relay HX which now releases. The earth returned on the P-wire from the succeeding equipment holds relay H before the withdrawal of the temporary holding earth at $B5$.

If all outlets on the selected level are engaged, the wipers rotate to the 11th contact when relay HX operates to the battery at YA. ***HX*1** disconnects the rotary stepping circuit and re-energizes relay CC. The operation of the 11th step cam springs (S) extends busy tone and flash to the calling subscriber. Contact ***S*1** prevents the operation of relay H and also operates the overflow meter for the level.

Serious congestion can occur by the unnecessary holding of linefinders and group selectors by line faults, etc. To obviate this, facilities are provided for the forcible release of the common switching equipment under such conditions. Contact ***CC*3** (Fig. 448) extends relay TM to the time pulse circuit. Within a period, varying between 1 to 4 min approximately, relay H is operated via ***TM*1**. ***H*5** and ***H*6** disconnect relay A, and $A1$ in turn releases B. At the same time a pulse of current is given to the vertical magnet during the release lag of B. The removal of the guarding earth at $B5$ releases relays H and K in the linefinder and in the subscriber's line circuit respectively. The fault condition now holds relay P in the subscriber's line circuit, whilst the release of $B2$ in the group selector releases in turn relays CC, TM, and H. $H4$ completes the rotary drive circuit and the selector restores to normal.

Final Selector. The final selector is of the 100-outlet type and offers facilities for P.B.X. groups of up to 10 lines. The circuit, which is illustrated in Fig. 449, is of the usual 2000 type. The impulsing, rotary hunting, and P.B.X. hunting circuit elements have all been described in early chapters of this volume.

The A relay is operated by the extended loop and in tunr operates relays B and C. C releases during the intertrain pause, and at $C3$ operates E. ***E*4** changes over the impulsing circuit to the rotary magnet, whilst ***E*6** pre-operates C in readiness for rotary stepping. The selector now responds to the final impulse train, at the end of which C again releases. $C3$ disconnects relay E and $C2$ applies the H relay to the P-wire for testing purposes. If the line is free, the battery from the called subscriber's K relay operates H. If, on the other hand, the required line is engaged, H cannot operate during the release lag of E and when the latter restores to normal, a circuit is provided for the G relay via $E2$. The G relay contacts return busy tone and flash as usual.

The hunt start battery is connected to the $P2$-wire of the first line in each P.B.X. group, whilst the last line of each P.B.X. group is connected to earth. Intermediate and non-P.B.X. lines are disconnected on the $P2$ arc. If the first line of a P.B.X. group is engaged, HS operates on the release of $C5$ and is held via its second coil. The restoration of $E6$ removes the short circuit from relay C, which again operates. A circuit is now provided for the energization of the rotary magnet, and as the wipers step to the next contact the G relay operates via the ***R*1** springs. This process continues until a free line is found or the wipers step to the last line of the group. If an intermediate line is free, relay H operates in series with the G relay, whilst ***G*5** disconnects the HS relay. The contacts of the latter in turn disconnect the circuit of G.

If the last line is engaged, relay H fails to operate and further hunting is prevented by the holding of the G relay to the $P2$ contact earth. ***G*5** releases HS, and ***G*3** prevents further hunting. As is usual with this type of circuit, night service facilities can be given on all lines of a P.B.X. group, with the exception of the first.

If the called party clears but the calling party continues to hold the connexion, relay D is released and, because relay F is held, relay TM is operated to battery in the time pulse start circuit. After a period of from 1 to 4 min, relay G is operated via ***TM*3**. Relays A, B, E, F, H, and HR are released, and $F7$ releases relay TM. TM in turn releases G. The selector now returns to normal in the usual way and the calling loop is isolated in the subscriber's line circuit.

Provision is also made for forced release if a spare number is dialled.

Call Discrimination. In a small automatic exchange, such as a U.A.X. 13, it is not economical to provide separate groups of selectors to carry the several different types of traffic on the exchange. The final selectors, which are used on purely local connexions, are, for example, also required to

give trunk offering facilities when they are used on calls from the parent manual board. Similarly, ordinary lines and coin-box lines are served by a single common group of linefinders and group selectors, but it is necessary to identify the origin of each call so that coin-box subscribers can be suppressed on calls from distant exchanges dialled through the U.A.X. on a tandem basis.

(*b*) Facilities for the parent operator to cut into engaged connexions for the purpose of offering trunk calls. The circuit arrangements must be such that local subscribers cannot imitate the

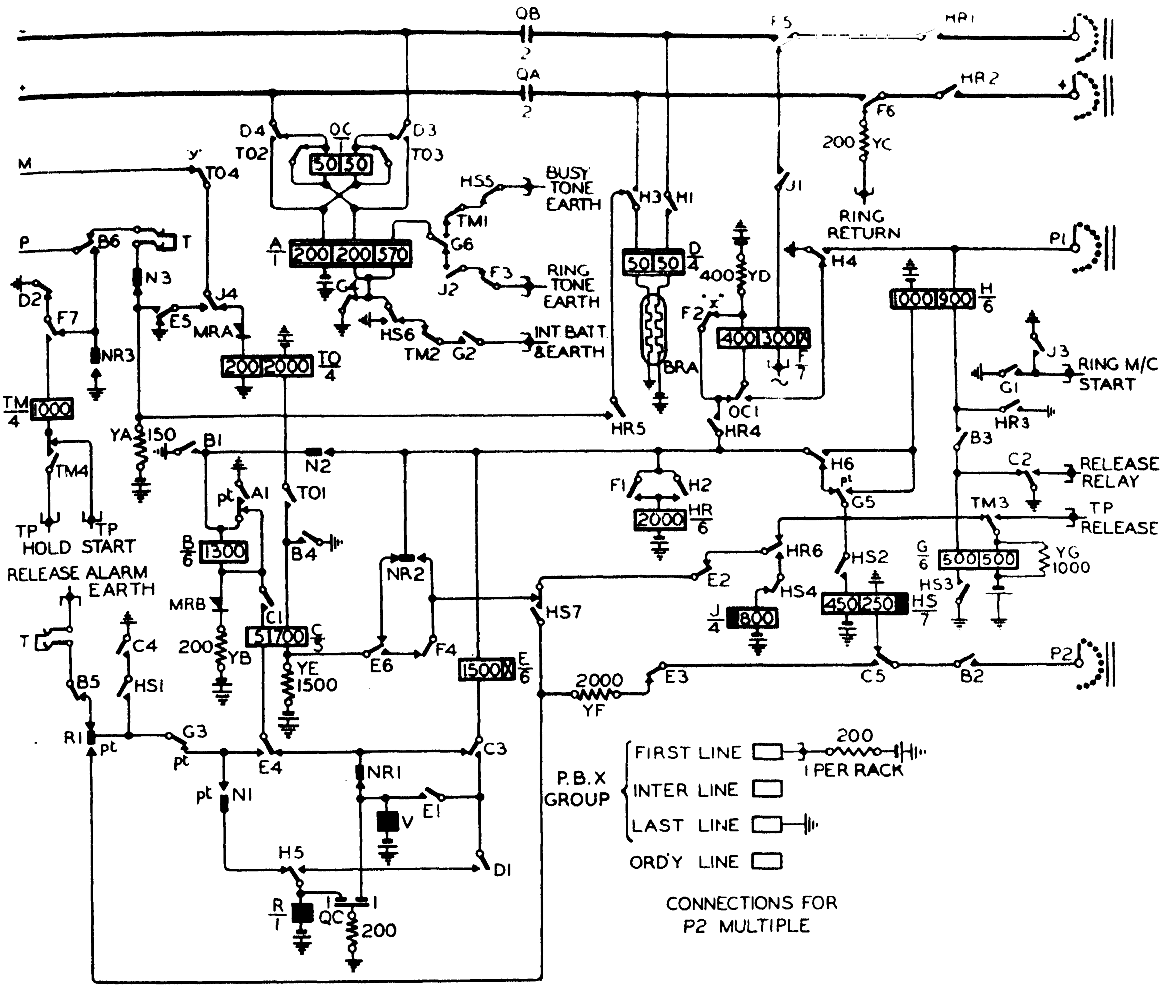


FIG. 449. U.A.X. 13 FINAL SELECTOR

prevented from obtaining automatic access to exchanges outside the unit fee area.

In order to provide for the differing facilities on calls of various types, it is necessary to introduce a system of discriminating signals which can be used to set up the required conditions on each type of call. The more important requirements are:

(*a*) Facilities whereby any dialling code restrictions on the outgoing junction routes are trunk offering cut-in facility. Where an exchange is dependent upon the U.A.X. 13 for access to the parent centre, the circuits must provide for the repetition of the trunk offering signals at the U.A.X. 13.

(*c*) Facilities for discriminating between calls from ordinary lines and from coin-box subscribers so that the latter can be barred access to outgoing junction routes which involve more than a unit fee charge.

(*d*) Facilities for utilizing a single group of junctions from the U.A.X. which will carry traffic not only to the parent manual board, but also to the parent exchange automatic network. This same group of circuits must also provide for a distinctive calling signal at the parent manual board if a call emanates from a coin-box line.

(*e*) Facilities whereby "0" level calls from a dependent U.A.X. can be switched at the U.A.X. 13 to the parent centre without the necessity for a routing digit.

The various discriminating signals introduce some complexities in the U.A.X. switching circuits, and it is desirable to examine the more important discriminating features separately before proceeding to a description of the complete U.A.X. junction terminations.

Suppression of Route Restrictions on Tandem Traffic. Route restriction equipment is often provided on the outgoing junctions from a U.A.X. 13 to prevent a subscriber from dialling codes which would extend him to an exchange beyond the range of the multi-metering equipment. Such route restriction facilities are also required to prevent irregular dialling on a route which is designed to carry only traffic of fixed fee. The route restriction equipment is associated with the outgoing junction circuit and consists (as will be seen later) of a uniselector which counts the routing digits dialled by the subscriber. If the digits are such that they would route the caller beyond the range of the metering equipment, the uniselector operates a discriminating relay which, in turn, disconnects the caller from the junction and returns N.U. tone.

If such an outgoing junction route is seized by a telephonist or a subscriber on a distant exchange, then the route restriction requirements no longer apply. If the call originates from a telephonist, there are no metering considerations, and it may greatly facilitate the handling of traffic if the operator can interdial through the U.A.X. to other exchanges which are beyond the multi-metering range of the U.A.X. subscribers. Similarly, if a call originates at a distant automatic exchange, fee determination and route restriction equipment is provided on the outgoing junctions from that exchange. It may so happen (and often does in practice) that an automatic exchange *A* interdials through an intermediate exchange *B* to obtain a third exchange *C* which is within multi-metering range of *A*. Exchange *C* may, however, be outside the multi-metering range of exchange *B*. It is therefore necessary to restrict access by subscribers on exchange *B* on the outgoing junction route to exchange *C*, whilst permitting subscribers on exchange *A* to dial over the same group of junctions.

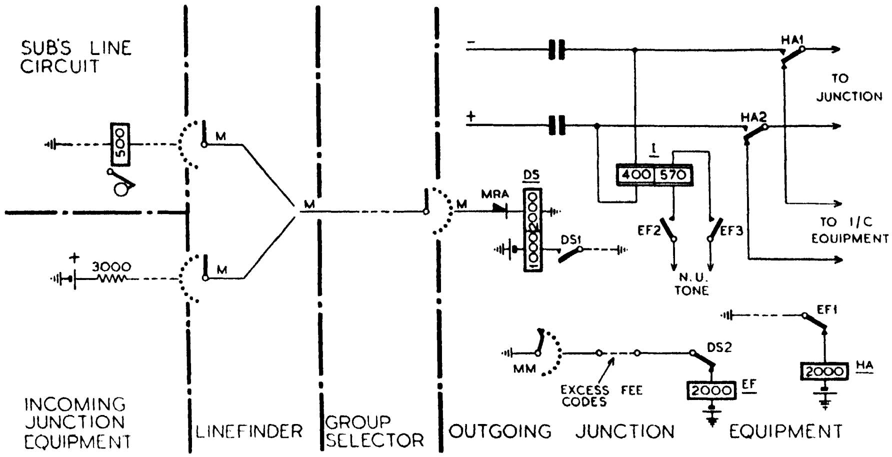


FIG. 450. SUPPRESSION OF ROUTE RESTRICTIONS ON TANDEM CALLS

The requirements can be met by the provision of a discriminating signal which is passed forward to the outgoing junction equipment when the circuit is seized by an incoming junction to the U.A.X. Fig. 450 shows the basic features of this discrimination circuit. It has been seen that all incoming junctions are terminated on the banks of the linefinders in exactly the same way as local subscribers. When a local subscriber originates a call, his earthed meter is extended forward over the *M*-wire in readiness to receive the metering pulse on an effective call. On incoming junctions

the meter is replaced by a + battery potential through a resistor of 3000 Ω. This condition is extended forward over the meter wire through the linefinder and group selector to operate relay *DS* in the outgoing junction equipment. The presence of rectifier *MRA* makes relay *DS* responsive only to + battery potentials on the *M*-wire. (As will be seen later, there are other discriminating relays which will respond to — potentials on the *M*-wire.) When the outgoing junction equipment is seized by an incoming junction, relay *DS* operates and locks at ***DS*1** for the duration of the call. Contact ***DS*2** disconnects the circuit of the excess fee discriminating relay (*EF*) in the route disconnect impulsing to step the group selector and final selector. If the required line is engaged, busy tone and flash are returned to the operator, and a further signal must be transmitted to the U.A.X. equipment if the operator desires to cut into an established conversation for the purpose of offering a trunk call. The only practicable d.c. signalling scheme is to apply an earth or a battery to the holding loop from the parent exchange. The consequent unbalance of the current in the two line wires can then be made to operate a cut-in relay at the U.A.X. In practice, the trunk offering signal is an earth applied to the holding loop from the parent exchange.

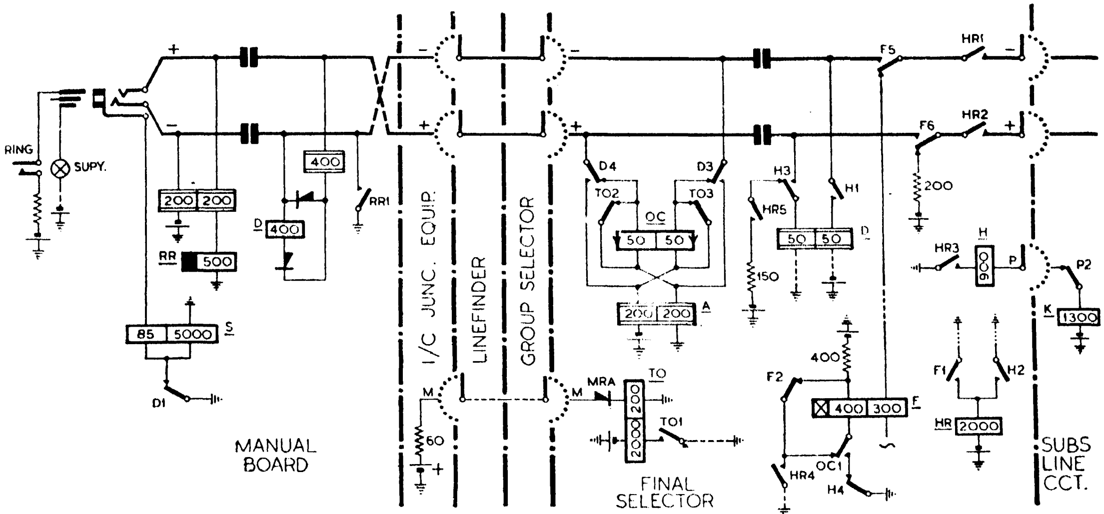


FIG. 451. TRUNK OFFERING TO A U.A.X. 13 SUBSCRIBER

restriction equipment, so that if an excess fee code is dialled, relay *EF* cannot operate and the call proceeds without restriction. If this same outgoing junction equipment is seized by a local subscriber, the absence of the + potential on the *M*-wire prevents the operation of *DS*, so that, if an excess fee code is dialled, relay *EF* is operated from the digit counting uniselector (*MM*). ***EF*2** and ***EF*3** return N.U. tone to the caller, whilst ***EF*1** disconnects the switching relay *HA* so that the call is isolated from the junction and the latter is available for incoming traffic.

Trunk Offering. It has been seen that there are no separate trunk offering selectors at a U.A.X. 13 and that the trunk offering facility is incorporated in the normal final selector circuit. On calls incoming to the U.A.X. from the parent manual board, the calling condition is a loop from the parent exchange, which is followed by loop-

It is a matter of some importance that earth faults on a local subscriber's line should not be permitted to imitate the trunk offering signal. It is, moreover, undesirable that any local subscriber should be able to cut into an established call by the malicious application of an earth to one or other of the lines at his instrument. In order to meet these requirements, it is necessary to have a discriminating signal in the U.A.X. so that the final selector will provide the trunk offering facility in response to an earth signal from the parent operator but will ignore any such signals on local calls or on incoming junction calls where the trunk offering facility is not required.

Fig. 451 shows the circuit elements concerned in the offering of a trunk call to a subscriber on a U.A.X. 13. On any incoming junction route where the trunk offering facility is required, the *M*-wire in the incoming junction equipment is connected

to + battery via a 60 Ω resistor (note the difference between this condition and the high resistance + battery provided for the clearance of route restrictions). When the call is set up to a final selector, the + battery on the *M*-wire is extended to operate relay *TO* in the final selector circuit. *TO* now locks for the duration of the call, and at ***TO*2** and ***TO*3** removes the short circuit from the windings of relay *OC*. If the required number is engaged, busy tone and flash are returned to the operator as previously described (see Fig. 449). If she so desires, the operator can cut into the line of the engaged subscriber by operating the ringing key associated with the cord in use. At a sleeve control exchange the operation of the

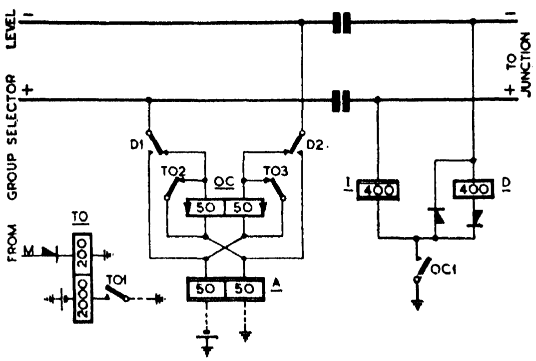


FIG. 452. REPETITION TO DEPENDENT EXCHANGE OF TRUNK OFFERING SIGNAL

ringing key extends − battery over the tip of the plug to operate relay *RR* in the outgoing junction relay set. ***RR*1** in turn applies an earth to the − line. Whilst the ringing key is thrown, the call is held from this earth over the − line, one coil of relay *OC*, one coil of relay *A*, to battery. Relay *OC* is differentially wound. Under normal conditions the currents in its two windings neutralize so that the relay does not operate. The application of the earth to the holding loop ceases the current in one winding and increases the current in the second winding. Relay *OC* now operates, and at ***OC*1** completes a circuit for relay *F*. ***F*1** in turn operates relay *HR*, whilst ***F*2** provides a locking circuit for relay *F* when the ringing key at the manual exchange is restored. ***HR*5** operates relay *D* over one coil. Contacts ***D*3** and ***D*4** reverse the line current back to the manual exchange to operate relay *D* in the outgoing junction relay set and thus to darken the cord circuit supervisory lamp. The operator is now extended through ***F*5**, ***F*6**, and ***HR*1**, ***HR*2** to the required subscriber. The subscriber can now be asked if he is willing to accept a trunk call, and if he agrees he is instructed to replace his receiver. When the local call has been cleared, relays *P* and *K* in the subscriber's line circuit restore to normal, and relay *H* operates to the battery condition on the *P*-wire. ***H*3** disconnects the holding circuit for relay *D*, and the restoration of *D*3 and *D*4 restores the direction of the line current to release relay *D* at the manual exchange, and thereby to light the cord circuit supervisory lamp. On receipt of this signal the operator again momentarily throws the ringing key, and the consequent application of the earth to the loop causes relay *OC* to operate for a second time. ***OC*1** disconnects the holding circuit for relay *F* which releases. (***H*4** is now operated.) Ringing current is transmitted to the required subscriber via *F*5 and *F*6, and, when the subscriber replies, the re-operation of relay *F* extends the subscriber to the *D* relay. *D* now re-operates and again reverses the line current back to the manual exchange to darken the supervisory lamp. The circuit is now in readiness for the connexion of the trunk call.

In cases where a distant exchange is dependent upon the U.A.X. 13 equipment for access to the parent manual board, it is necessary to provide facilities whereby a trunk offering signal from the parent switchboard can be repeated at the U.A.X. 13 and re-transmitted to the dependent exchange. Fig. 452 shows the circuit elements of the trunk offering repetition feature in the outgoing junction equipment to a dependent U.A.X. Relay *TO* operates to the + battery on the *M*-wire as usual, and the application of an earth to the holding loop operates relay *OC* as before. ***OC*1** now repeats this earth signal on the outgoing junction to the dependent exchange. Relay *D* responds to the various supervisory signals during the process of trunk offering, and repeats these supervisory signals back to the parent exchange at contacts ***D*1** and ***D*2**.

On calls from the parent exchange, it is usually necessary to provide both trunk offering and facilities for over-riding route restrictions. It has been seen that the discriminating signal for the trunk offering facility is a low resistance + battery on the *M*-wire, whilst the signal for clearance of route restrictions is a + battery potential through a high resistance. The outgoing junction equipment can be made to differentiate between these two signals by providing two relays, viz.:

Relay DS which will operate to the small current through the 3000 Ω resistor to give clearance of route restrictions.

Relay TO, of low resistance, which is marginally adjusted not to operate with the current through

3000 Ω but to operate to a + battery through a resistance of 60 Ω. The operation of relay *TO* gives the trunk offering facility.

The high value of current on the *M*-wire required to give the trunk offering facility will, of course, also operate relay *DS* to over-ride the route restrictions. Hence this arrangement automatically gives both facilities on any incoming junction which is arranged to provide trunk offering. Fig. 453 shows the circuit arrangements. Relay *DS* operates to *any* + potential on the *M*-wire (i.e. either through 60 Ω or through 3000 Ω) and at **DS2** extends the *M*-wire to relay *TO*. Relay *TO* is, however, adjusted so that it does not operate to the light current condition, and responds only to the heavier current from an incoming junction termination arranged for trunk offering. The operation of one relay (*DS*) before the second relay (*TO*) is applied to the *M*-wire considerably facilitates the design of the discriminating relays. If both relays were connected in parallel to the *M*-wire, it would be difficult to obtain sufficient current in relay *DS* to obtain operation under the light current condition unless the operate windings of relay *TO* were of high resistance. Increasing the resistance of *TO* makes it more difficult to obtain the necessary marginal adjustments.

Coin-box Discrimination. In a U.A.X. 13 the coin-box lines are distributed amongst the various linefinder groups along with the lines of ordinary subscribers. On calls routed over outgoing junctions, it is necessary to determine whether the call originates from a coin-box line or from an ordinary subscriber in order that multi-fee routings can be denied to the coin-box user. This in turn necessitates some form of discriminating signal between the linefinder and the outgoing junction group to indicate whether the call is from a coin-box or from an ordinary line. It will be recalled that in the U.A.X. 12 this discrimination is obtained by providing an earth-connected meter on ordinary lines, and a battery-connected meter on coin-box lines. In the U.A.X. 13 differentiation is obtained by segregating the coin-box lines on one particular level of the linefinder bank. This permits of arrangements so that, when the linefinder is stepped to the coin-box level, a special signal is forwarded to the subsequent selectors to indicate that the call emanates from a coin-box subscriber.

If an outgoing junction route gives access to an exchange within the unit-fee area, then both ordinary and coin-box subscribers must be given access to that route. Equipment must, however, be provided in the outgoing junction equipment to prevent a coin-box subscriber from dialling *through* the objective exchange to other points beyond the unit-fee range. In cases such as this, it is clearly necessary to pass forward the coin-box discrimination signal to the outgoing junction equipment. Alternatively, an outgoing junction route may be directly connected to an exchange beyond the unit-fee area of the U.A.X. There is no point in allowing a coin-box subscriber to seize the outgoing junction equipment on such a route and then to apply N.U. tone because the route is barred. It is preferable to stop such calls at the group selector stage and to return N.U. tone to the coin-box line from the group selector. This avoids the unnecessary engaging of outgoing junction equipment on ineffective calls.

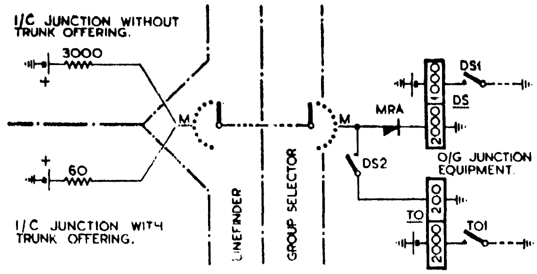


FIG. 453. COMBINATION OF TRUNK OFFERING AND ROUTE CLEARANCE SIGNALS

Fig. 454 gives the method of providing a coin-box discrimination signal and shows how the signal is used either in the group selector or in the outgoing junction equipment to prevent a coin-box user from obtaining access to a multi-fee route. All coin-box lines are located on level 8 of the linefinder group. It is inadmissible to mix ordinary and coin-box subscribers on this level. The linefinder mechanism is provided with normal post springs (*NP1*) which operate only on level 8. If a call originates from a coin-box line, a 150 Ω − battery is returned via the normal post springs to the *CB*-wire of the group selector. This wire is connected to one side of the vertical marking bank on all levels which give access to outgoing junction routes. If any particular level gives access to a route which must be *completely* barred to coin-box users, the appropriate level of the second half of the vertical marking bank is connected to relay *CC*.

The circuit is arranged so that relay *CC* is operated by contact **C3** when the group selector is first seized. Relay *C* is the usual end-of-impulse-train switching relay, and holds during vertical stepping. At the end of the impulse train, *C* restores and, under normal conditions, releases relay *CC*. The release of *CC* starts up rotary

drive, and the wipers are rotated over the selected level until a free outgoing junction is seized. The call is then switched to the junction in the normal manner.

If the level to which the group selector is stepped is barred to coin-box users, then the – battery via the linefinder normal post springs is extended over the *CB*-lead and via the vertical marking wipers to hold relay *CC*. At the end of the impulse train, *C*3 releases, but *CC* remains held. ***CC*1** now returns N.U. tone to the marking bank and over the *M*-wire to operate relay *CB* in the outgoing junction equipment. *CB* now locks over a local circuit for the duration of the call.

After a short period of lag, *CC*5 restores to remove the marking condition and to reconnect the meter wire. The coin-box subscriber now proceeds to dial the code of the required exchange. If this code relates to an exchange beyond the unit-fee radius, one or more of the fee determination relays (*MA*, etc.) are operated from the digit

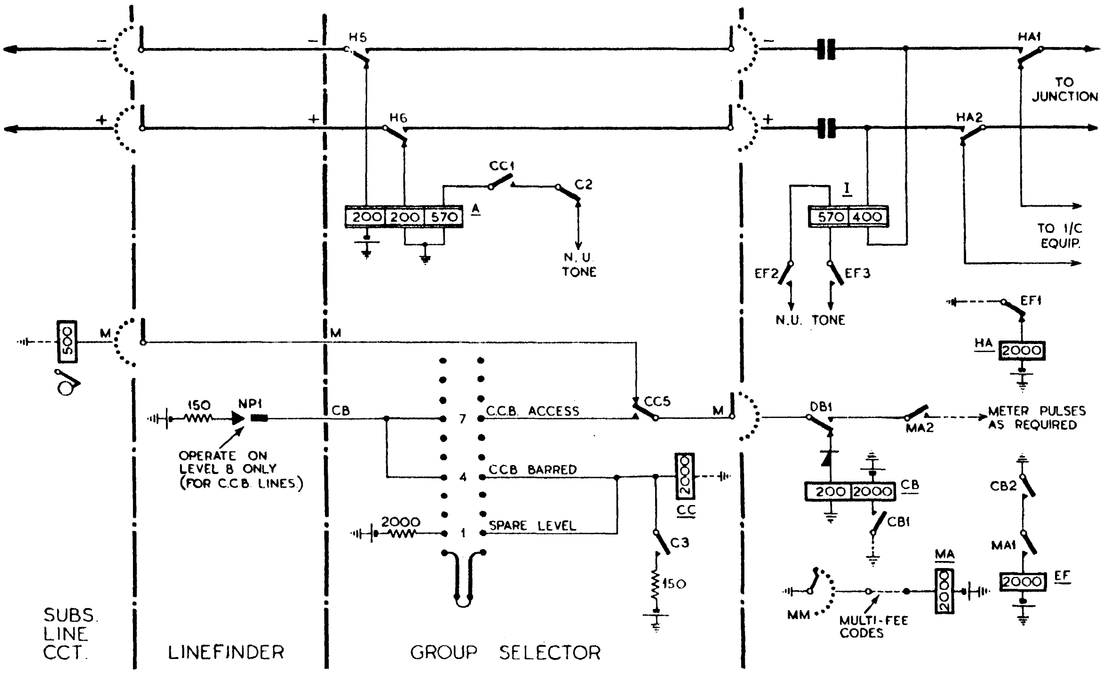


FIG. 454. COIN-BOX DISCRIMINATION ON OUTGOING JUNCTION CALLS

caller, whilst other contacts of the *CC* relay prevent rotary drive.

Similar conditions exist if the caller (either an ordinary line or a coin-box line) dials a spare level. In this case a 2000 Ω battery is applied locally in the group selector to all spare levels. When the wipers are stepped to any such level, the battery potential holds relay *CC*, and N.U. tone is returned to the caller.

If coin-box lines are to be permitted access to any particular junction route, the appropriate level of the vertical marking bank is connected via ***CC*5** to the *M*-wire of the group selector. If a coin-box subscriber dials this level, the wipers rotate and seize the first free junction. During the release lag of relays *C* and *CC* the 150 Ω battery from the linefinder is extended via the vertical counting uniselector (*MM*). The operation of any such multi-fee relay completes a circuit from contact ***CB*2** to operate relay *EF*. ***EF*2** and ***EF*3** now return N.U. tone to the caller, whilst ***EF*1** allows the switching relay *HA* to restore to permit of incoming junction traffic.

If the call originates from an ordinary subscriber, the absence of the coin-box discriminating signal prevents the operation of relay *CB*. The fee determination relays (*MA*, etc.) operate as before, and, when the called subscriber replies, contact ***DB*1** extends the appropriate number of meter pulses to the *M*-wire to operate the meter in the calling subscriber's line circuit.

Combined "9" and "0" Level Working. The U.A.X. 13 provides facilities for the use of a single group of junctions to cater both for calls to the

parent operator and traffic which is to be passed via the automatic switching equipment at the parent exchange. This common group of junctions is accessible from level 9 and also from level 0 of the group selectors. If the outgoing junction equipment is seized from level 0, a discriminating signal is passed forward to establish the correct signalling conditions on the junction to route the call to the parent manual board. If, on the other hand, a parent exchange junction is seized from level 9 of the group selectors, a discriminating signal is passed forward to establish the appropriate signalling conditions to route the call to an incoming selector at the parent exchange. In addition, facilities must be provided for differentiating between calls from ordinary subscribers and calls from coin-box subscribers on traffic routed to the parent operator. (It is a service requirement that coin-box calls should give a distinctive calling signal at the automanual exchange.)

The method of signalling over the parent exchange junctions is the same as that employed from a U.A.X. 12 to its parent exchange. Briefly:

(*a*) A "9" level call (i.e. a call to the automatic equipment at the parent) utilizes a loop calling signal which is followed by loop-disconnect impulsing.

(*b*) An "0" level call from an ordinary subscriber provides a calling signal which consists of — battery on the + wire.

(*c*) An "0" level call from a coin-box subscriber provides a calling signal which consists of earth on the — wire.

The supervisory condition on "9" level calls is, as usual, a reversal of the line current. On "0" level calls from ordinary subscribers the supervisory signal is an earth returned on the — wire, whilst the supervisory signal on coin-box calls is a — battery returned from the parent exchange on the + wire of the junction. The system of signalling for "0" level calls has been fully described in Chapter XIV (see Fig. 417). The practical arrangements are somewhat complicated due to the fact that the supervisory relay cannot be connected at the U.A.X. termination until such time as the initial calling signal has been received and recorded at the parent termination.

Fig. 455 shows the circuit elements at a U.A.X. 13 which provide the appropriate signalling conditions on the junction. To avoid confusion, the sequence of operations which is necessary before the supervisory relay can be applied to line has been omitted. The net result of these operations is that connexion X is not completed until after

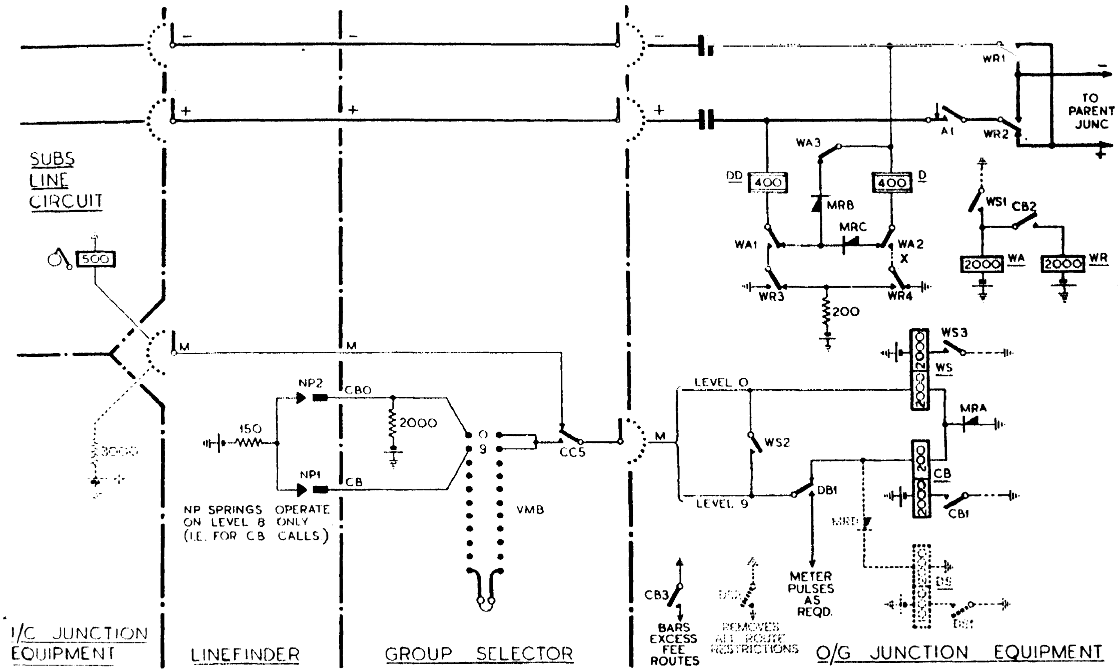


FIG. 455. DISCRIMINATING SIGNALS FOR COMBINED "9" AND "0" LEVEL WORKING

the initial calling signal has been received at the parent termination.

The basic discriminating signals are:

(*a*) A — battery via 2000 Ω is transmitted from the group selector over the *M*-wire to the outgoing junction equipment when an "0" level call is required by an ordinary subscriber.

(*b*) This is replaced by — battery via 150 Ω if the call originates from a coin-box subscriber.

(*c*) There is no signal over the *M*-wire to the outgoing junction equipment on "9" level calls from ordinary subscribers.

(*d*) A — battery via 150 Ω is transmitted over the *M*-wire on "9" level calls from coin-box subscribers.

Differentiation between conditions (*b*) and (*d*) is obtained by wiring out the *M*-wires for levels 9 and 0 separately to the junction relay group, i.e. the 150 Ω battery which indicates an "0" level call from a coin-box subscriber is transmitted over the *M*-wire of level 0, whilst a similar condition extended over the *M*-wire of level 9 indicates a "9" level call from a coin-box subscriber.

On "0" level calls from an ordinary subscriber, the 2000 Ω battery from the group selector is extended via the vertical marking bank and wipers to the "level 0" *M*-lead of the junction equipment. This battery operates relay *WS*, and ***WS*1** in turn operates *WA*. ***WA*1** applies battery via relay *DD* to the + wire of the junction to give the required calling signal to the parent exchange. After the signal has been acknowledged, connexion *X* is established so that the earth connected relay *D* is applied to the — wire in readiness to receive the supervisory signal.

If the "0" level call originates from a coin-box line, the low resistance — battery on the *M*-wire (level 0) operates relay *WS* as before, and ***WS*2** extends the battery to relay *CB*, which also operates and locks. (The principle is the same as that adopted for the *DS* and *TO* relays—see Fig. 453.) ***WS*1** operates relay *WA*, whilst ***CB*2** operates relay *WR*. ***WR*1** and ***WR*2** now reverse the — and + lines of the junction, whilst ***WR*3** and ***WR*4** reverse the battery and earth connexions to relays *DD* and *D*. Earth is now transmitted via ***WR*3**, ***WA*1**, the *DD* relay, to the — line of the junction. In due course a battery connected supervisory relay *D* is applied to the + line to receive the answering signal.

On "9" level calls from an ordinary subscriber there is no signal over the *M*-wire to operate either *WS* or *CB*. The closure of contact ***A*1** (relay *A* is, of course, operated from the subscriber's loop as usual) now completes a loop calling signal via *DD*, *WA*1, *MRB*, and *WA*3. Impulsing can now proceed (when the *DD* and *D* relays are short-circuited by *C* relay contacts—not shown), and, in due course, relay *D* operates when the called subscriber answers. Contacts of relay *D* cause the operation of ***DB*1** which connects the appropriate number of meter pulses to the *M*-wire.

On "9" level calls from coin-box subscribers, the 150 Ω battery in the linefinder is extended via level 9 of the vertical marking bank, and the "level 9" *M*-wire to the junction equipment. Relay *CB* now operates but, since *WS* is normal, relay *WR* does not operate and the loop calling conditions (as for an ordinary subscriber) are maintained. Other contacts of relay *CB*, however, forward a signal to the multi-metering or route restriction equipment so that access is barred if the coin-box subscriber dials a multi-fee code. Access from coin-box telephones to level 9 is, of course, given only where the parent exchange is within unit-fee metering distance of the U.A.X. If the parent exchange is beyond this range, level 9 calls from coin-box subscribers are barred at the group selector stage by commoning the vertical marking bank as already shown in Fig. 454.

It will be noted that the discriminating signals from the 9 and 0 levels of the group selector are transmitted over the *M*-wire only during the period for which contact ***CC*5** is operated. As we have seen from earlier paragraphs, this contact remains operated after switching for a period equal to the combined release lags of relays *C* and *CC* (i.e. for some 150 msec). The discriminating relays (*WS* and *CB*) must operate during this period and lock over local circuits for the duration of the call.

In most cases it is necessary to provide access to the parent junction route from interdialling exchanges. The incoming junctions from such exchanges have the usual 3000 Ω + battery connected to the *M*-wire. On an interdialled call, therefore, the discriminating signals from the group selector vertical marking bank are first transmitted to the outgoing junction equipment of the parent route and then, when contact *CC*5 restores, the + battery condition from the incoming junction equipment operates relay *DS*. Contacts of relay *DS* remove all route restrictions from the outgoing parent route as already described.

Incoming Junction from Parent or Non-dependent Exchange. Fig. 456 shows the termination at a U.A.X. 13 suitable for use on a unidirectional junction from the parent exchange or from a non-dependent exchange. The circuit provides for alternative access to a second choice control set as already described in connexion with Fig. 446.

In addition, facilities are provided for forwarding discriminating signals to give through dialling access (Fig. 450) or, if required, trunk offering (Fig. 451). The circuit also provides for the locking out of the junction equipment under forced release conditions, and for returning busy tone to the caller should dialling commence before the incoming junction has switched to a control set.

The circuit is designed to receive a loop calling signal from the distant exchange which operates the *P*-wire, whilst ***K8*** applies the appropriate discriminating condition to the *M*-wire. If the incoming junction does not require trunk offering facilities, this discriminating condition is a + battery via the 3000 Ω resistor *YB*, but if trunk offering facilities are required *YB* is shunted by the 60 Ω resistor *YA*.

A pre-dialling path via the control relay set is provided by contacts ***HA2***, ***HA6***, or ***HB2***, ***HB6*** until such time as the linefinder switches to the

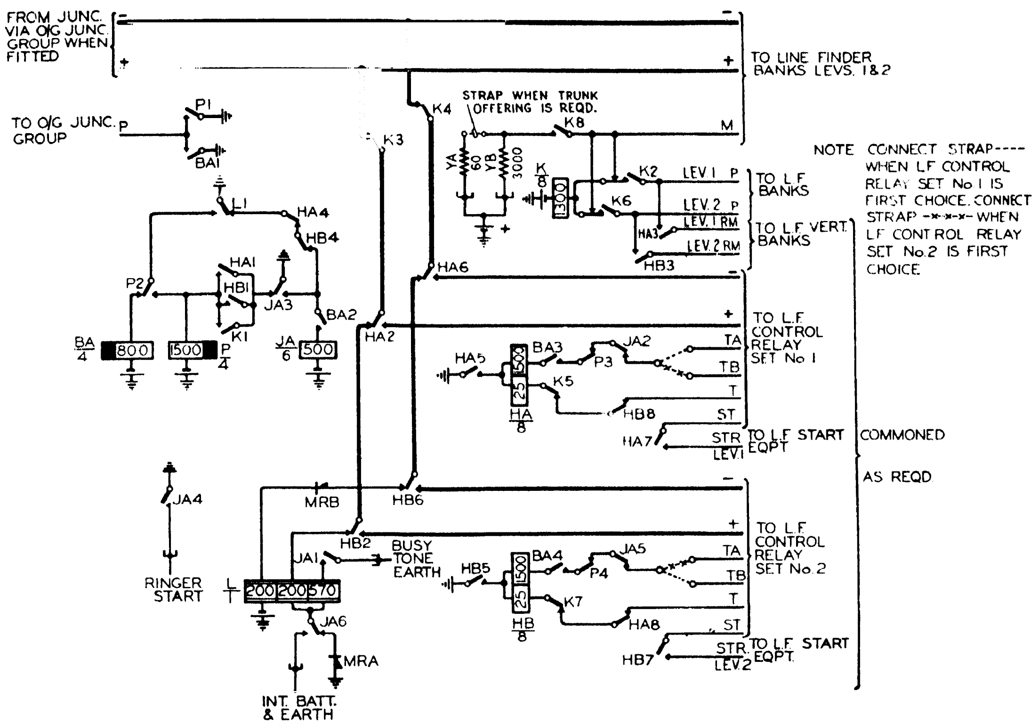


FIG. 456. INCOMING JUNCTION FROM PARENT OR NON-DEPENDENT EXCHANGE

relay *L*. ***L1*** energizes *BA*, and ***BA1*** guards the *P*-wire if the circuit is used in conjunction with an outgoing relay group. ***BA3*** and ***BA4*** apply the *HA* and *HB* relays to the *TA*- and *TB*-leads of the two control relay sets serving the linefinder group. Relay *HA* or relay *HB* switches to a control relay set as already described, and contacts ***HA3*** or ***HB3*** mark the appropriate level of the linefinder bank. ***HA1*** or ***HB1*** operates relay *P*, and ***P2*** disconnects *BA*. ***P1*** now provides an alternative guarding earth on the *P*-wire.

In due course the linefinder reaches this level and rotates to find the appropriate rotary position in the bank. Relay *K* now operates over the *M*-wire from the earth applied at the group selector. ***K2*** or ***K6*** transfers the holding circuit of *K* to junction, when this path is disconnected at ***K3*** and ***K4*** to leave the speaking pair straight through to the group selector. The circuit is now set up for conversation and is held in this condition until the removal of the earth from the *P*-wire at the end of the call allows relay *K* to release.

Under C.S.H. or P.G. conditions, the earth is removed from the *P*-wire after a period of delay. The removal of this earth allows relay *K* to release, and the restoration of contacts *K3* and *K4* restores relay *L* to the speaking pair. Relay *L* operates to the calling loop, and at ***L1*** provides a holding circuit for relay *P* before it has had time to release after the restoration of *K1*. The fault condition is thereby locked to the line circuit until such time as the loop is removed.

It has been stated in earlier paragraphs that there is some slight danger of dialling commencing before relay *HA* or relay *HB* has switched to a free control set. Under these conditions the restoration of *L*1 at the first break impulse operates relay *JA*. ***JA*1** and ***JA*6** apply busy tone and flash to line, whilst ***JA*2** and ***JA*5** prevent the seizure of a control set. Relay *JA* is now held under the control of ***BA*2** until such time as the call is abandoned.

Outgoing Junction to Non-dependent Automatic Exchange. Fig. 457 shows the arrangements on an outgoing junction to a non-dependent automatic exchange. If desired, the circuit can be used with simple route restriction equipment on junctions which carry fixed-fee traffic. Alternatively it can be used in conjunction with full facility multi-metering equipment on junctions which carry traffic with different call charges.

The circuit provides the following facilities:

(1) Repetition of impulse trains to the junction and to the auxiliary route restricting or multi-metering equipment.

(2) The transmission of N.U. tone to the calling party should a barred or a spare code be dialled.

(3) Repetition of busy tone and flash to the calling party if the required line is engaged. (If the circuit is used in conjunction with common auxiliary equipment, busy tone and flash are also returned if this common equipment is engaged on another call.)

(4) Manual hold.

(5) Single- or multi-fee metering over the *M*-wire direct or from the auxiliary apparatus.

(6) Forced release of the junction if the caller dials a barred or a spare code.

(7) Forced release of the junction (under time pulse control) under P.G. or C.S.H. conditions.

Relay *A* operates to the loop extended from the previous selector, and at ***A*1** prepares the forward loop to the distant exchange. ***A*2** operates *B*, and ***B*1** provides a guarding and holding earth on the *P*-wire. ***B*2** operates *BA*, and ***BA*3** operates relay *HA* via the auxiliary equipment. (If such equipment is not fitted, the *EF*- and *EFA*-leads are strapped.) ***HA*1** starts the time pulse circuit in readiness for forced release under permanent loop conditions. ***HA*4** and ***HA*5** complete the loop on the outgoing junction, whilst ***HA*6** applies earth to the *P*-wire. The line current in the forward loop now operates relay *I* in readiness to receive busy conditions.

Relay *A* responds to the impulses dialled by the caller and repeats these impulses both to the junction and to the auxiliary equipment. Relay *C* operates on the first restoration of *A*2, and at ***C*1** cuts out the *D* and *I* relays from the impulsing loop. ***C*2** operates relay *CC*, whilst ***C*3** operates relay *CA*. ***CC*4** disconnects the time pulse start circuit, whilst ***CA*1** operates relay *BB*. ***BB*2** in turn operates relay *MD*.

At the end of the impulse train relays *C*, *CA*, and *CC* release. *C*1 and *CA*2 restore the *D* and *I* relays to the loop (note the two-stage drop-back feature). *CC*3 applies earth to the *C*-lead of the auxiliary equipment to give the required marking condition for fee determination or route restriction.

Assuming that the call is not to be barred, dialling proceeds, and in due course relay *D* operates when the called subscriber answers. ***D*1** releases relay *MD* and operates relay *DD*. ***DD*3** and ***DD*4** reverse the line current back towards the caller for supervisory purposes, and ***DD*6** prepares the circuit for the operation of relay *DA* at the next *S* pulse. The operation of ***DA*1** extends the metering lead from the auxiliary equipment, whilst ***DA*2** completes a circuit for *DB* to the *Z* pulse. The application of this pulse starts the metering cycle, and the appropriate number of meter pulses is applied to the *M*-wire via ***DA*1** and ***DB*6**. At the end of metering, *DA* releases but relay *DB* remains held for the duration of the call.

If the called subscriber is engaged, relay *I* releases to the first flash period, and at *I*1 releases *BB*. The next operation of ***I*1** energizes relay *BR*, which at ***BR*6** prepares the busy flash circuit. *I* again releases at the second flash period, and at *I*2 operates relay *DD*. ***DD*4** now applies busy flash battery to the + line. This busy flash circuit is substantially the same as that employed on auto-auto relay sets and has already been considered in earlier chapters.

On some routes the caller may obtain access to a distant manual exchange via the junctions to a non-dependent auto exchange. Facilities are provided for manual hold under these conditions. When the caller replaces his receiver, relay *A* releases and at *A*2 releases relay *B* and operates relay *C*. ***C*2** in turn operates *CC*, whilst ***C*4** allows relay *MB* to operate if the call is to a manual exchange. ***MB*1** now applies manual hold battery to the + wire, whilst ***MB*2** connects the recall relay *OH* to the − line. ***MB*3** provides an alternative holding condition to the *P*-wire. After a release lag period, *B* releases and at *B*2 disconnects *BA*. *BA*4 removes the forward loop and connects relay *MH* to the forward + line. *MH* operates to the battery from the manual exchange on the + line, and at ***MH*1** provides a hold circuit for relay *C* on the release of *BA*2. ***CC*1** in turn provides a hold circuit for *HA*. The connexion is therefore held until such time as the

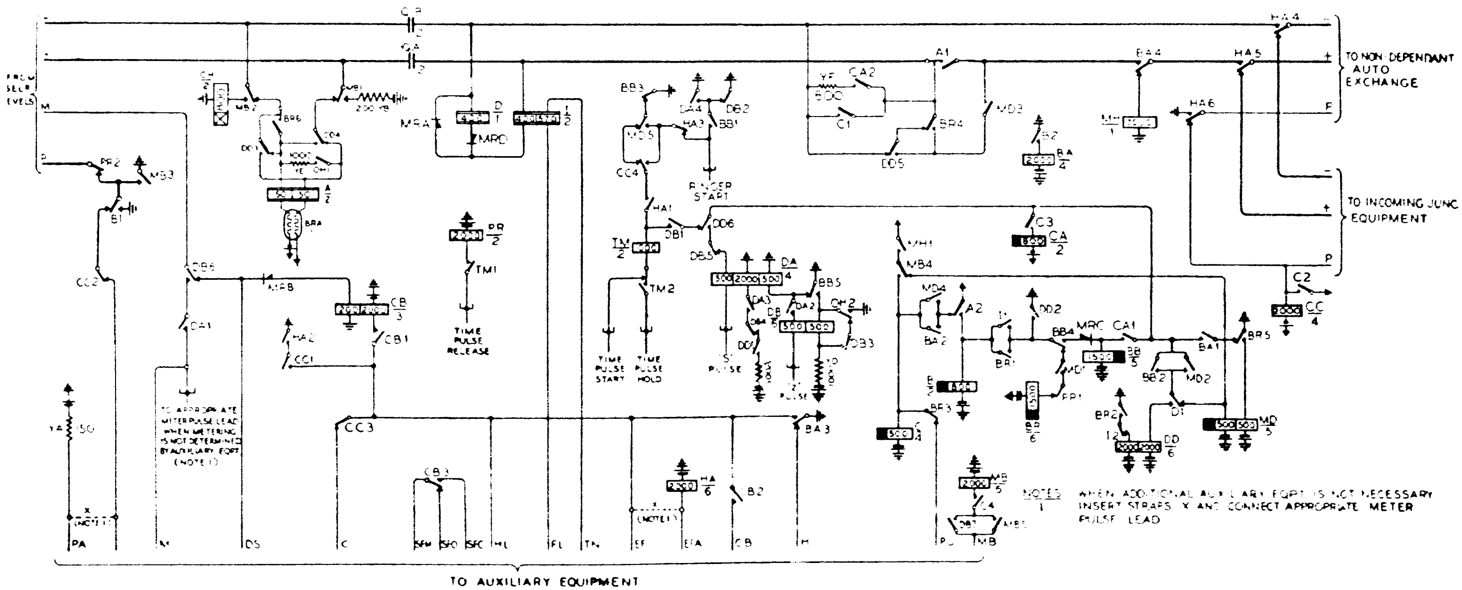


FIG. 457. OUTGOING JUNCTION TO NON-DEPENDENT AUTOMATIC EXCHANGE

operator withdraws her answering plug. If the caller should re-establish the loop during this period, relay *OH* operates and at ***OH*1** re-operates relay *A*. ***OH*2** operates relay *DB*. Relays *A*, *B*, *BA*, *BB*, *D*, and *I* now re-operate as already described, whilst relays *C*, *CA*, *CC*, *MB*, and *MH* are released. When the operator clears down under manual hold conditions, relays *MH*, *C*, *CC*, and *MB* release to restore the circuit.

If the caller seizes the junction circuit and delays dialling for a period of from 3 to 6 min, relays *TM* and *PR* operate. ***PR*2** disconnects the *P*-wire to release the preceding switches and the junction. Time pulse release also occurs if the caller fails to replace his receiver at the completion of conversation (i.e. under C.S.H. conditions). In this case the initial energization of *TM* takes place over contacts *BR*5, ***BA*1**, *DD*6, and ***DB*1**.

On calls from a coin-box subscriber, the circuit functions in a similar manner, except that relay *CB* is operated by the discriminating signal on the *M*-wire. ***CB*1** provides a local holding circuit, whilst ***CB*2** and ***CB*3** extend the coin-box discrimination condition to the auxiliary apparatus. If, on any call, the auxiliary equipment determines that the call is to be barred, relay *HA* is released by a disconnexion in the auxiliary equipment. *HA*4 and *HA*5 disconnect the caller from the junction, and N.U. tone is applied to the speaking pair from the auxiliary equipment over the *FL*- and *TN*-leads.

Relay *CC* is required if the junction is worked on a bothway basis. On such calls the earth returned on the *P*-wire from the incoming equipment operates relay *CC*, and ***CC*2** removes the battery condition from the incoming *P*-wire to guard the junction against seizure from the selector levels.

On release, the restoration of *A*1 short-circuits relay *I*. If the current in the forward loop at this time is not reversed (i.e. the called subscriber has cleared or has not answered) the short circuit can materially prolong the release lag of the relay. As a result a circuit is formed from the earth at *BR*5, via ***BA*1**, ***CA*1**, ***BB*4**, and ***I*1** to relay *B*. Rectifier *MRC* blocks this path and so prevents an extension of the *B* relay release time. It was found that the omission of this rectifier could (under certain circumstances) give rise to lock up on junctions worked on a bothway basis.

Route Discriminating Equipment. Fig. 458 shows the circuit arrangements of the "full-facility" route discriminating equipment which can be associated with an outgoing junction relay group when required. The circuit provides facilities for:

(1) Determination of the appropriate fee from the digits dialled by the subscriber.

(2) Multi-metering up to 4 units on any call.

(3) Return of N.U. tone and disconnexion of the junction if the caller dials a spare code or a code which would lead to an exchange outside the multi-fee range.

(4) The barring of all except unit-fee calls from coin-box subscribers.

(5) The removal of all routing restrictions on tandem calls (i.e. on all calls routed through the U.A.X. from some distant centre).

(6) Taking into use common auxiliary equipment when it is not possible to accommodate all the dialling codes on the uniselector of the individual route discriminating equipment.

The circuit is substantially similar to the multi-metering equipment provided at a U.A.X. 12 which has already been described in Chapter XIV. In essence it contains a 6-level uniselector, 5 banks of which are used for digit counting. There are 4 switching relays *SA*, *SB*, *SC*, and *SD*, together with a 5th relay *SE* which is brought into use when the code dialled necessitates the use of the common auxiliary equipment. There are 3 meter discrimination relays (*MA*, *MB*, and *MC*), the contacts of which are arranged to apply the appropriate metering conditions to the *M*-wire of the junction relay set. Relay *EF* is brought into use when a spare or barred code is dialled. Relay *DS* responds to the + battery discriminating signal forwarded from an incoming junction relay group. Contacts of *DS* disconnect excess-fee dialling codes from the *EF* relay, and thereby prevent the release of the junction and the return of N.U. tone when such a code is dialled by a distant exchange.

Once the correct discriminating conditions have been set up, the operation of contacts ***MA*1**, ***MB*1**, or ***MC*1** allows relay *ZM* to operate, and ***ZM*1** provides a homing circuit for the uniselector in readiness for the next call. The discriminating relays are, however, held over the *HL*-lead from the junction relay group for the duration of the call.

Common Route Discriminating Equipment. In certain exchanges the number of dialling codes is in excess of the capacity of the uniselector in the individual route discriminating circuit. In such circumstances auxiliary equipment on the lines of Fig. 459 is provided. This equipment is common to all the discriminating circuits associated with the junctions, and accommodates the additional codes which it is not possible to provide on the individual uniselectors.

If the initial digits show that the code requires the use of the common equipment, relays *SE* and

SF of the individual discriminating equipment (Fig. 458) operate. If the common equipment is free, relay *K* also operates and extends earth to energize relay *T* in the common equipment. Other contacts of relay *K* (and its reliefs *KR* and *KK*) switch the various discriminating relays and the restoration of *K*1 removes the earth from the *T*-lead. Relay *T* in the common equipment now releases, and at *T*2 provides a homing circuit for the uniselector. It will be noted that, whereas the individual discriminating equipment is held for the duration of the call, the common equipment

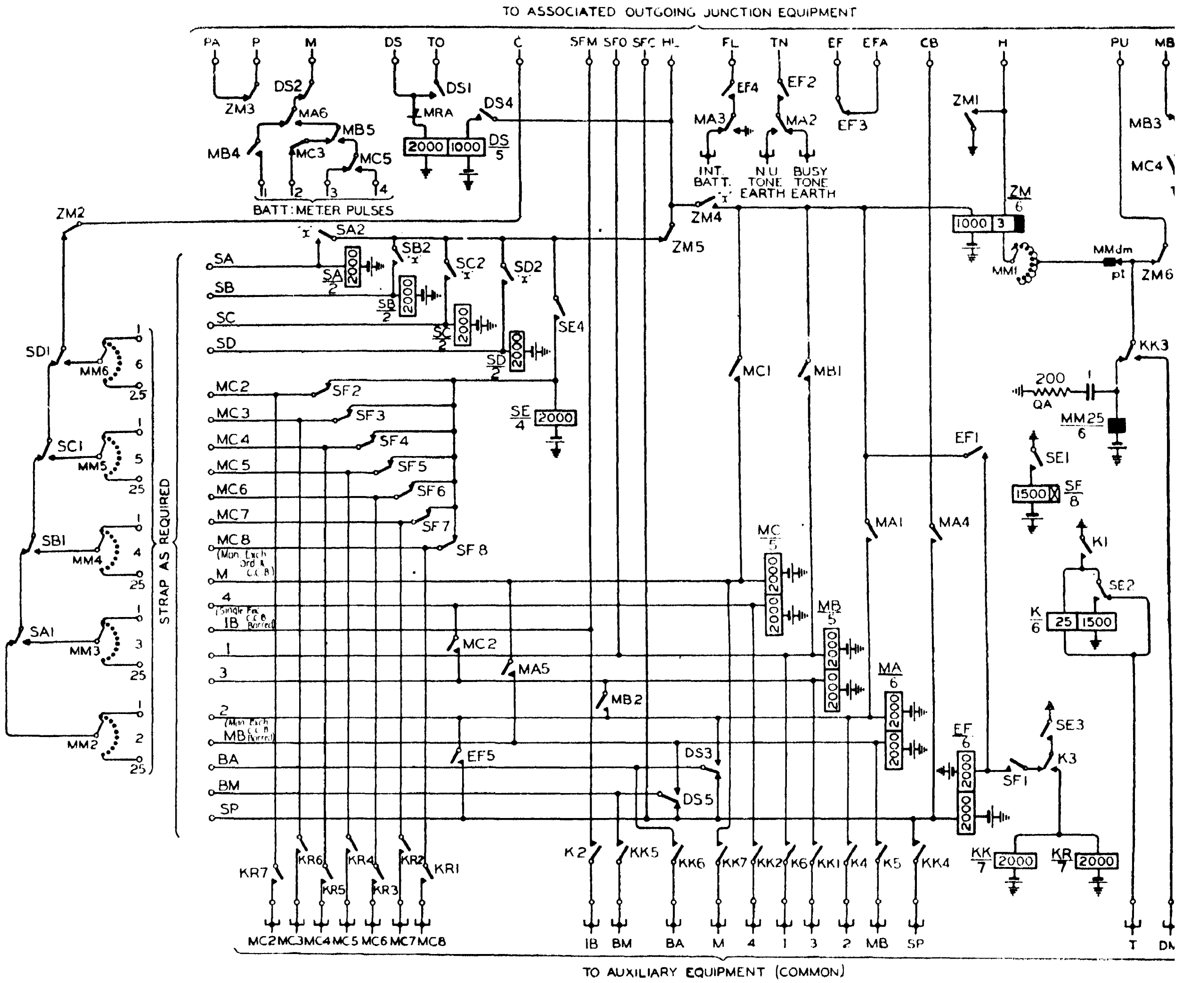


FIG. 458. AUXILIARY EQUIPMENT FOR MULTI-METERING AND ROUTE RESTRICTION

terminals of the cross-connexion field to the common equipment. The incoming impulse trains are similarly diverted to the common equipment over the *DM*-lead. Subsequent impulse trains step the *MM* uniselector, and the bank contacts of the latter are cross-connected as required to the terminals leading to the various discriminating relays, etc.

Once the correct discrimination conditions have been established, the release of relay *SE* (Fig. 458) short-circuits, at ***SE*2**, relay *K*, and the is in use only whilst the last one or two digits of the routing code are counted. After this the circuit is released and is available for use on any other call.

Route Restriction Equipment. In some circumstances all the traffic on an outgoing junction route from a U.A.X. 13 requires a uniform fee. It is then uneconomical and unnecessary to provide the full route discrimination equipment with its switching and discriminating relays for fee determination. Safeguards must, however, be

taken to prevent a calling subscriber from obtaining irregular access by interdialling through the distant exchange equipment to other exchanges which are beyond the fee fixed for the route in question. The requirements can be met by the provision of a simple form of route restriction equipment on the lines of Fig. 460. This equipment is supplied per outgoing junction, and gives facilities for counting one train of impulses. If the first routing digit indicates a barred or spare code, N.U. tone is returned to the calling party and the junction is released for further traffic.

If a spare or a barred code has been dialled, the appropriate contact of the *MM*3 arc is cross-connected to the *EF* relay, and the latter operates at the end of the digit. ***EF*5** disconnects the uniselector magnet as before, whilst ***EF*1** provides a holding circuit for relay *EF*. ***EF*2** and ***EF*4** complete a circuit for the transmission of N.U. tone to the caller. ***EF*3** disconnects the operate circuit for the junction switching relay to leave the junction free for incoming calls. (This, of course, applies only when the junction is worked on a bothway basis.)

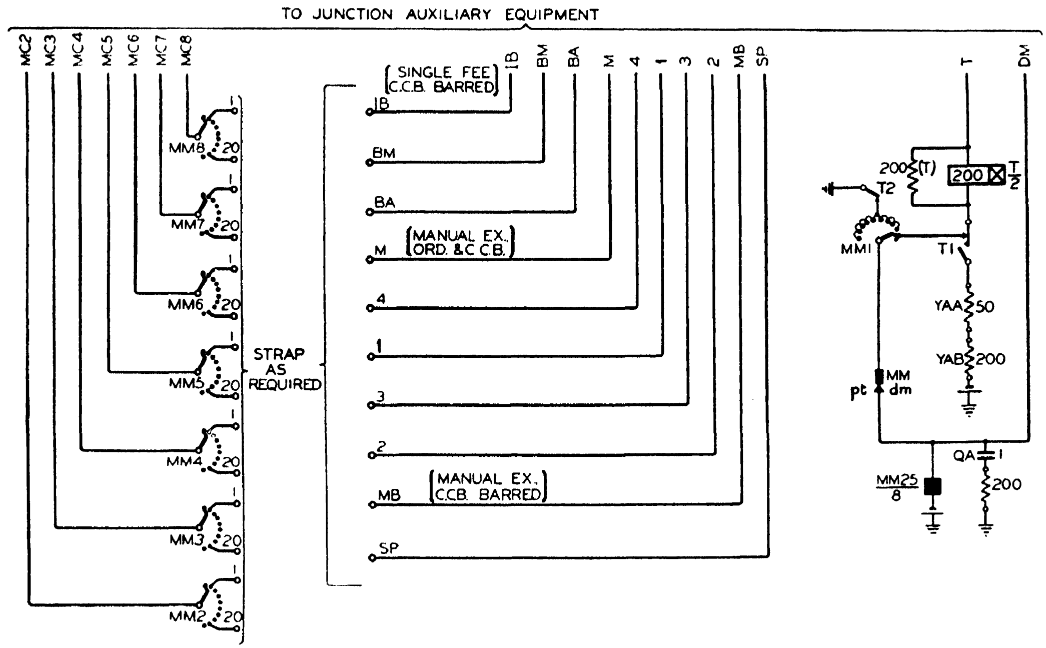


FIG. 459. COMMON ROUTE DISCRIMINATING EQUIPMENT

The first train of impulses transmitted to the junction is repeated (in the junction relay set) to the route restriction equipment over the *PU*-lead. These impulses energize the magnet of uniselector *MM*, and the wipers are stepped to the contact corresponding to the digit dialled. At the conclusion of the impulse train, earth is applied to the *C*-lead as described previously, and is extended via the *MM*3 wiper to the cross-connexion field. If a permissible code has been dialled, the bank contact of the *MM*3 arc is cross-connected to relay *MA* which operates to the earth on the *C*-wire. Contact ***MA*1** disconnects the magnet circuit to prevent any further trains of impulses from stepping the uniselector. ***MA*2** holds relay *MA* to the earth on the *HL*-lead, which is maintained from the junction equipment for the duration of the call.

At the end of the call, earth is removed from the *HL*-lead and is applied to the *H*-lead. Relay *EF* or relay *MA* now releases, whilst a homing circuit is provided for the uniselector via the *MM*1 arc. A further arc of the *MM* uniselector (*MM*2) is included in the *P*-wire circuit so that the testing battery is not reconnected until the route restriction equipment has returned to normal from the previous call.

Bothway Junction to Parent Exchange. Fig. 461 shows the circuit arrangements at a U.A.X. 13 for the termination of junctions to the parent exchange. The arrangements are somewhat more complex than the circuits previously considered owing to the large number of facilities required on such routes. The complete circuit caters for:

(1) "0" *Level Calls from Ordinary Subscribers* (or from interdialling exchanges) to the parent

manual board. On such calls a discriminating signal (2000 Ω — battery) is received over the *M*-lead from the group selector. This signal arranges the circuit so that the calling condition to the parent exchange is a battery on the + wire. When the operator replies, the transmission circuit is completed and manual hold conditions are prepared. No metering is provided on this type of call.

(2) "0" *Level Calls from Coin-box Subscribers* to the parent manual board. A different discriminating signal (a low resistance — battery) is forwarded to the junction circuit over the *M*-lead from the linefinder. Receipt of this discriminating signal arranges the circuit connexions so that earth is connected to the — wire for the calling signal to the manual exchange. When the operator replies, the transmission circuit is completed as before, and manual hold conditions are prepared. There is no metering.

(3) "9" *Level Calls* to the parent automatic exchange. The discriminating signals are as follows:

(*a*) If the call originates from a coin-box line, the earth from the subscriber's meter is preceded by a — battery signal over the *M*-wire. This sets up conditions in the auxiliary equipment to bar all except unit-fee calls.

(*b*) If the call is from an interdialling exchange, a + battery signal extended from the incoming junction termination temporarily withdraws the route restriction arrangements in the auxiliary equipment associated with the junction circuit.

The seizure signal on the junction is in each case a loop, and the digits dialled by the calling party are repeated to the parent exchange in the form of loop-disconnect impulses. Impulses are also transmitted to the auxiliary equipment for the purpose of fee determination and route discrimination (on calls from local subscribers).

(4) "0" *Level Calls from a Dependent U.A.X.* to the parent manual board. The incoming termination of the dependent exchange junction is provided with a junction hunter which searches for and seizes a free line to the parent exchange. This automatically busies the associated junction relay group to guard against intrusion from local calls or interdialled traffic.

(5) *Incoming Calls from Parent Exchange* to a subscriber on the U.A.X. or to an exchange obtained via the U.A.X. The incoming portion of the circuit provides for the usual access to first and second choice control sets with facilities for pre-dialling through the control set until such time as the linefinder seizes the calling junction. Busy tone and flash are returned if dialling commences before the junction has been extended to a control set. The seizure signal on incoming calls is a loop followed by loop-disconnect impulsing.

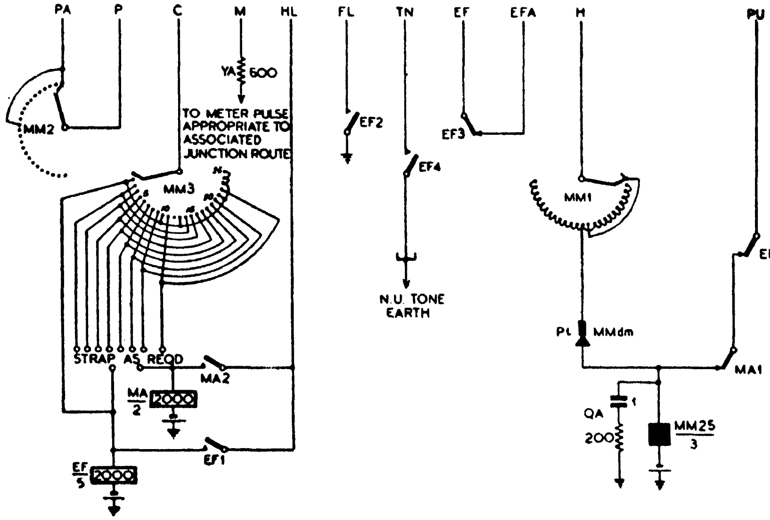


FIG. 460. CIRCUIT OF ROUTE RESTRICTION EQUIPMENT

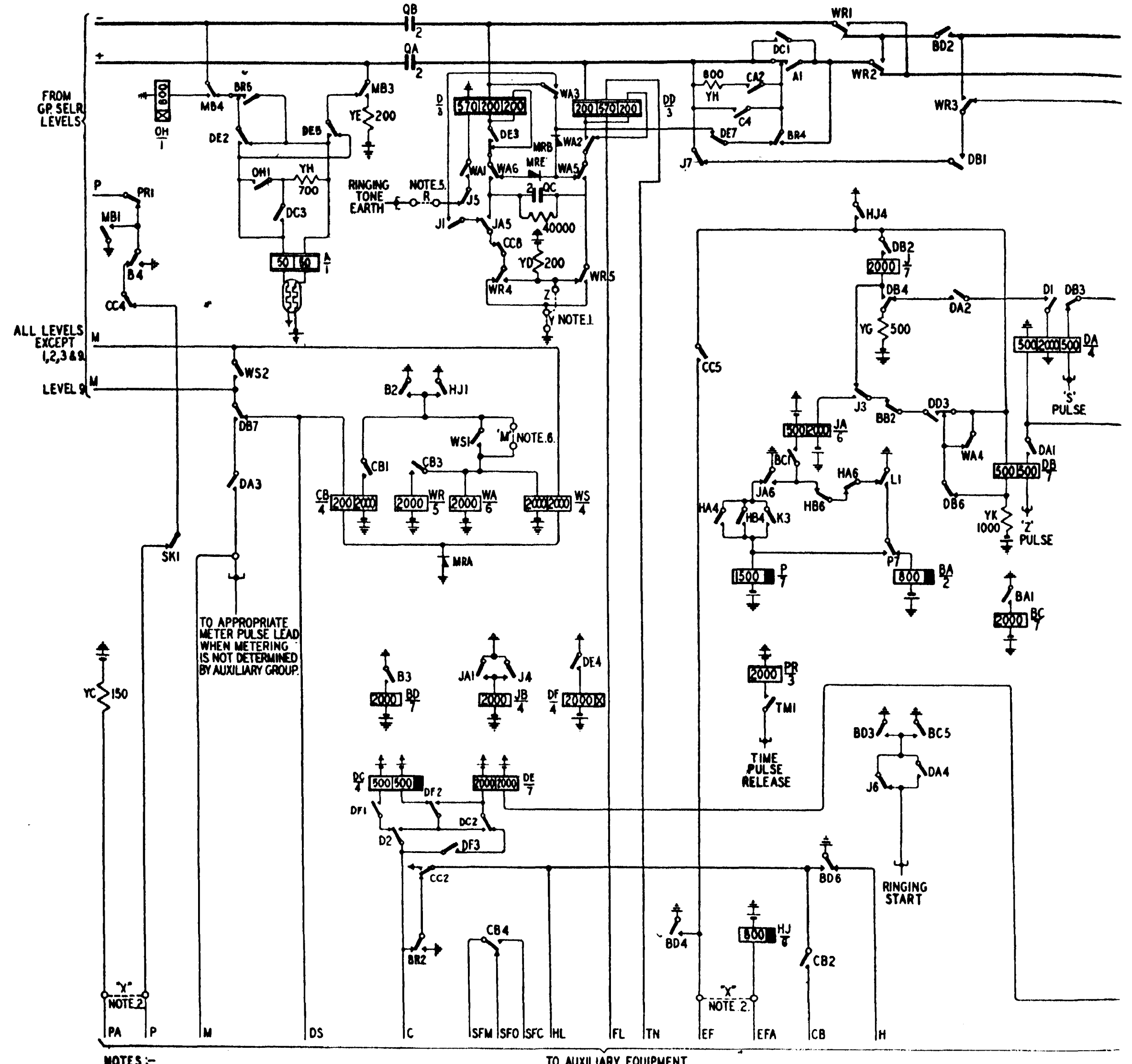
The circuit provides for the transmission of ringing tone on calls to a directly connected manual board. Forced release is also applied under P.G. and C.S.H. conditions.

The junction signalling principles and the method of discriminating between calls of various types have already been considered in earlier paragraphs. It remains, therefore, only to examine the sequence of circuit operations for each type of call. Space will not permit of a comprehensive description of the functions of all contacts, etc., and only the main steps in the circuit operation are considered in the following paragraphs.

"0" Level Calls. When the group selector is stepped to level 0, — battery via a 2000 Ω resistor is extended to the junction equipment over the *M*-wire. This battery operates relay *WS* which, at ***WS*1**, prepares a holding circuit for itself and an operating circuit for relay *WA*. ***WA*1** completes the ringing tone circuit, whilst contacts ***WA*3**, ***WA*5**, and ***WA*6** arrange the outgoing junction signalling conditions so that battery via *YD*, *WR*5, ***WA*5**,

WA2, and one coil of relay *DD* is applied to the + wire.

Relay *A* operates to the calling loop extended from the group selector, and at **A1** completes the relay *HJ* either directly or via the auxiliary equipment. ***HJ2*** and ***HJ3*** extend the calling conditions to the junction. ***HJ5*** engages the circuit on the junction hunter banks, and operates relay *SK*.



NOTES:—
1. INSERT STRAPS 'W' & 'Y' WHEN WORKING TO 50 OR 60 VOLT EXCHS. INSERT STRAP 'Z' WHEN WORKING TO 22 OR 40 VOLT EXCHANGES.
2. INSERT STRAPS 'X' (2) WHEN AUXILIARY EQUIPMENT IS NOT EMPLOYED.
3. STRAP —✕✕— WHEN TO IS REQUIRED. OMIT STRAP WHEN T.O. IS NOT REQUIRED
4. CONNECT STRAPS ---- WHEN LF CONTROL RELAY SET 1 IS FIRST CHOICE. CONNECT —✕✕— WHEN LF CONTROL RELAY SET 2 IS FIRST CHOICE.
5. INSERT STRAP 'R' WHEN WORKING TO PARENT DIRECT.
6. WHEN WORKING TO NON-PARENT MANUAL EXCHANGE INSERT STRAP "M".

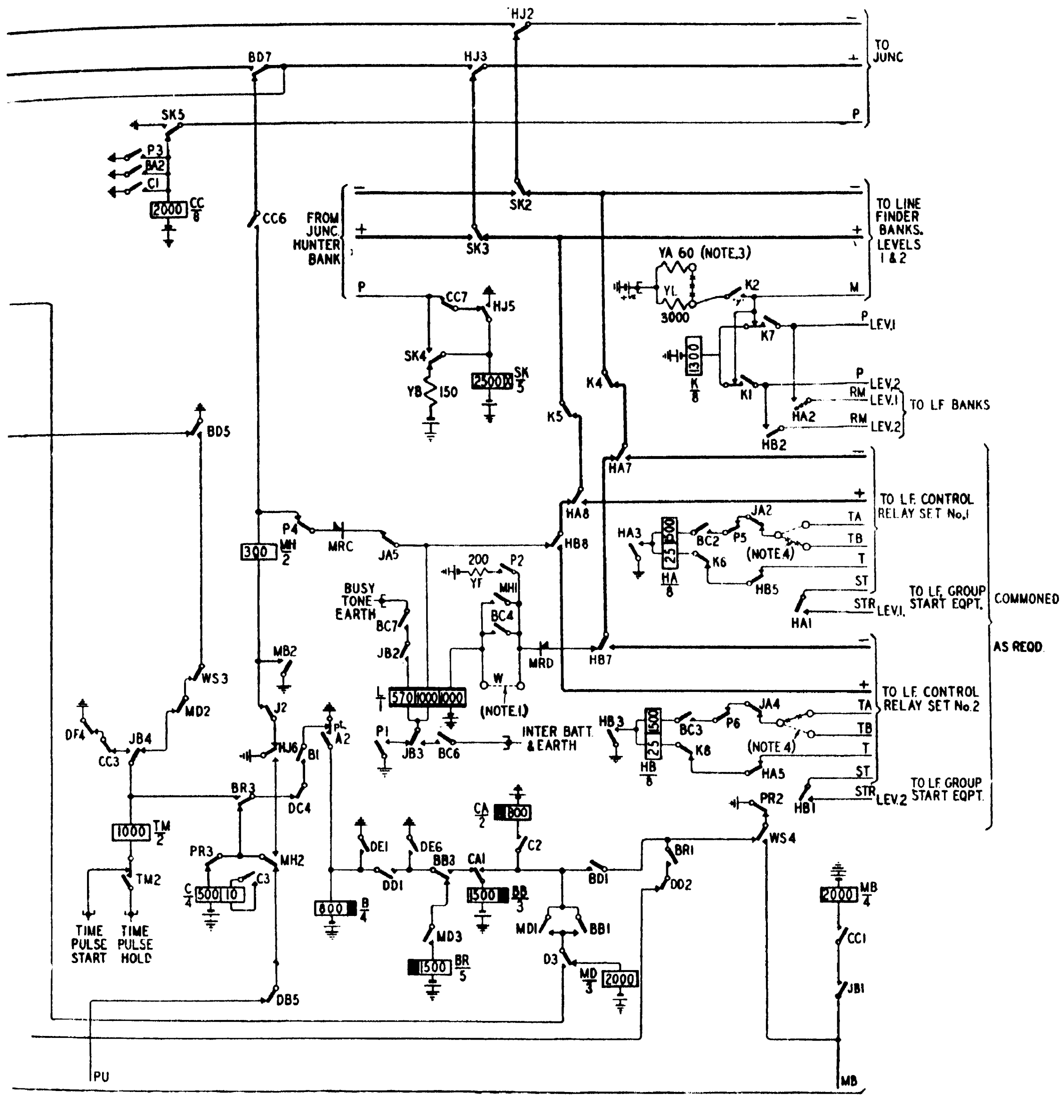
FIG. 461. BOTHWAY JUNCTION

+ line in readiness for the transmission of the calling condition to the parent exchange. ***A2*** operates relay *B*, ***B2*** completes the holding circuit for *WS* and *WA*, ***B3*** operates relay *BD*, and ***B4*** applies the necessary guarding and holding conditions to the incoming *P*-wire. ***BD4*** operates

Relay *DD* operates in series with the calling battery on the + line, and at ***DD3*** removes the short circuit from one coil of relay *DB*. This allows *DB* to operate and prepare the circuit for receiving the acknowledgement signal from the distant exchange. When the operator inserts

an answering plug into the line jack, the + line is disconnected, and the cessation of current allows *DD* to release. *DD*3 now removes the short circuit from relay *J*, which operates. *J*1 pulse release circuit in readiness for C.S.H. conditions.

The earth signal on the − wire causes the distant exchange equipment to restore the +



Circuit to Parent Exchange

extends full earth to the − line to give the "acknowledgment received" signal to the manual termination. ***J*4** operates relay *JB*, whilst ***J*5** disconnects the ringing tone. ***JB*1** prepares a circuit for relay *MB* under manual hold conditions, and ***JB*4** prepares the time line conditions. Relay *DD* now re-operates, and at ***DD*3** energizes *JA*. ***JA*5** connects the supervisory relay *D* to the − line.

In due course the distant exchange operator throws her speaking key, and the return of the supervisory battery condition on the − line

operates relay *D*. ***D*2** operates *DC*. ***DC*2** in turn completes an operate circuit for *DE*. ***DE*2** and ***DE*5** reverse the line current towards the caller to give supervisory conditions if the call originates from a manual exchange. ***DE*4** operates relay *DF*. ***DF*2** holds relay *DE* and releases relay *DC*. The circuit is now established for conversation.

If the call originates from a coin-box subscriber, the circuit operates as described above, except that relay *CB* is operated to the low resistance battery on the *M*-wire after the closure of contact ***WS*2**. ***CB*1** provides a holding circuit for *CB*, whilst ***CB*2** and ***CB*4** extend coin-box discriminating conditions to the auxiliary equipment. ***CB*3** operates relay *WR* which, at ***WR*1** and ***WR*2**, reverses the — and + lines so that earth is now connected to the — wire of the junction via ***WR*5** and relay *DD*. When the acknowledgment signal is received from the distant termination, the operation of ***J*1** applies a 200 Ω battery to the + line, and, when the — line current has been restored, the operation of relays *DD* and *JA* applies the battery connected *D* relay to the + line in order that it can receive an earth supervisory signal from the manual board termination.

If the calling subscriber replaces his receiver whilst the plug is still in the junction jack, the release of relay *A* allows relay *B* to release, and relay *C* operates during the release lag of ***B*1**. ***C*1** in turn operates *CC*, whilst ***CC*1** operates relay *MB*. ***CC*2** provides an alternative earth for holding the auxiliary equipment in advance of the release of *BD*6. ***CC*5** provides a holding circuit for *HJ* in readiness for the release of *BD*4. ***CC*6** prepares a circuit for the operation of *MH*.

***MB*1** in operating provides an alternative holding earth to the incoming *P*-wire, whilst ***MB*2** connects earth to the *MH* relay. ***MB*3** repeats the manual hold condition back over the + line, whilst ***MB*4** connects the *OH* relay to the — line in readiness to receive a recall signal.

After a period of lag, *B* releases, and at *B*3 releases *BD*. *BD*7 now completes a circuit for relay *MH* to operate from the manual hold battery over the + line of the junction. ***MH*2** holds relay *C*, and *C* in turn holds relays *CC* and *MB* to maintain the holding earth on the *P*-wire. Should the subscriber recall during manual hold conditions, relay *OH* operates to the loop, and at ***OH*1** re-operates relay *A*. Relays *A*, *B*, *BD*, *JA*, *D*, and *DD* now re-operate as previously described, and relays *C*, *CC*, *MB*, *MH*, and *OH* are released.

"9" Level Calls. On calls extended to the junction via level 9 of the group selector, the circuit is arranged to apply a loop (via relays *D* and *DD*) to the junction. Contact *A*1 repeats the incoming impulse trains to the automatic equipment at the parent centre, whilst *A*2 repeats the impulses over the *PU*-wire to the auxiliary equipment. Relay *B* operates on the first closure of *A*2 and ***B*3** energizes relay *BD*. Relay *C* operates at the first impulse and retains during the train due to the short circuit across its 10 Ω winding. ***C*2** operates *CA*, whilst ***C*4** excludes the *D* and *DD* relays from the junction impulsing loop. ***CA*1** operates *BB*, and ***BB*1** operates relay *MD*.

Relays *C*, *CC*, and *CA* release at the end of each impulse train (*CA* providing a two-stage drop-back feature). After each train, the release of *CC*2 extends earth to the *C*-wire of the auxiliary equipment to carry out wiper switching or to operate discriminating relays as required.

If the called subscriber is free, the reversal of the forward line current operates relay *D*, and ***D*3** releases relay *MD*. ***D*2** operates *DC*, and ***DC*2** completes a circuit for the operation of *DE*. ***DE*2** and ***DE*5** now reverse the direction of the incoming line current to give supervisory conditions to the distant manual exchange. ***DE*4** operates *DF* and, after a period of lag, ***DF*2** releases *DC*. Relay *DA* operates (via ***D*3**) to the first *S* pulse, and at ***DA*1** prepares a circuit for the operation of relay *DB* on the subsequent *Z* pulse. Receipt of the *Z* pulse operates relay *DB* which, at ***DB*2** and ***DB*4**, completes a circuit for relay *J*, whilst ***DB*7** extends the meter pulse lead from the auxiliary equipment to the *M*-wire of the circuit.

If the called subscriber is engaged, busy tone and flash are returned from the distant exchange. Relay *DD* releases during the first busy flash period, and at *DD*1 releases relay *BB*. *BB*3 in releasing prepares for the operation of relay *BR* at the termination of the flash period, i.e. when *DD* re-operates. ***BR*1** now prepares the circuit for the operation of *DE* when *DD*2 releases at the commencement of the next flash period. ***DE*1** applies busy hold conditions to relay *B*, whilst ***DE*5** applies busy flash battery to the + line of the circuit. *BR* responds in this way to each period of flash until such time as the circuit is released.

Incoming Calls. The circuit is designed to receive a loop seizure signal from 50 V exchanges, or a battery signal over the + line from 22 V or 40 V manual exchanges. In the latter case, relay *MH* operates to the calling condition, and ***MH*1** returns battery via relay *L* to the — line. Receipt of this signal at the manual exchange switches the conditions to loop signalling.

If the call originates from a 50 V automanual exchange, relay *L* operates to the loop, and at ***L*1** operates relay *BA*. ***BA*1** in turn operates *BC*, whilst ***BA*2** operates relay *CC*. ***BC*2** and ***BC*3** complete the circuits of the switching relays *HA* and *HB*, whilst ***CC*4** and ***CC*7** engage the junction on the banks of the group selectors and the junction hunters. Relay *HA* or relay *HB* switches the junction through to a free control set as previously described, and also operates relay *P*. ***P*3** retains relay *CC* in readiness for the release of *BA*. The operation of *HA* or *HB* disconnects the circuit for relay *L*, and *L*1 in turn releases *BA*. When the linefinder seizes a calling junction, relay *K* operates over the *M*-wire and holds to the earth on the *P*-wire. ***K*2** extends the discriminating + battery on the *M*-wire, whilst ***K*4** and ***K*5** disconnect the pre-dialling path. The call is now routed direct to the − and + wires of the linefinder and thence to the group selector.

The circuit provides for forced release under C.S.H. or permanent loop conditions, and also for the return of busy tone should dialling be commenced before a free control set is seized.

Incoming Junction from Dependent U.A.X. It is not always economical to provide direct junctions from every U.A.X. to the parent exchange. In some cases a small U.A.X. is dependent upon the equipment at a nearby U.A.X. 13 for obtaining access to the parent manual board. In these circumstances the circuit arrangements must provide for a caller to reach the manual board operator by the dialling of a single digit "0." This digit is utilized at the local exchange to select the route to the U.A.X. 13, and it follows that the equipment at the intermediate U.13 exchange should provide for the automatic extension of the caller to the parent centre on receipt of manual board calling conditions from the dependent exchange. The route from the dependent exchange to the U.A.X. 13 may also be required to carry local traffic to the U.A.X. 13 or to other nearby automatic exchanges obtainable via group selector levels at the U.A.X. 13. It is, moreover, necessary to differentiate between ordinary subscribers and coin-box subscribers on calls to the parent switchboard. This involves the repeating of the discriminating signal received from the dependent exchange over the junction route from the U.A.X. 13 to the parent centre.

The standard signalling arrangements for combined routes are used between the dependent exchange and the U.A.X. 13. Thus:

(*a*) A loop calling signal from the dependent exchange indicates that the call is to the auto network.

(*b*) A battery on the + wire indicates a call from an ordinary subscriber to the parent switchboard.

(*c*) An earth on the − wire indicates a call from a coin-box subscriber to the parent switchboard.

The relay group at the U.A.X. 13 provides facilities for directing the call via a linefinder to a group selector if the calling condition is a loop. If, however, the calling condition is an earth or battery on one of the two conductors, a uniselector associated with the incoming junction circuit is made to hunt for a free junction to the parent exchange. When this junction has been found, the signalling conditions are repeated forward to the parent centre where they are used to operate the "ordinary" or "coin-box" calling lamps, as required. No common switching equipment at the U.A.X. 13 is engaged for such calls, but it is, of course, necessary to engage the parent exchange junction on the banks of the group selectors.

Fig. 462 shows the circuit arrangements of an incoming junction from a dependent U.A.X. Apart from the facilities mentioned above, the circuit provides for:

(*a*) The repetition of manual hold from the parent exchange to the dependent exchange.

(*b*) The return of supervisory and metering conditions to the dependent exchange.

(*c*) The transmission of busy tone to the caller under premature dialling conditions.

(*d*) The return of busy tone if all junctions to the parent exchange are engaged.

(*e*) The transmission of ringing tone to the calling party when a direct junction to the parent exchange is seized.

(*f*) Forcible release under C.S.H. and P.G. conditions.

(*g*) The removal of route restriction conditions on calls dialled through the U.A.X. 13.

On "0" level calls from an ordinary subscriber, relay *LA* operates to the battery extended over the + wire from the dependent U.A.X. ***LA*1** engages the outgoing portion of the circuit, if provided. ***LA*2** operates relay *MB*. ***MB*4** operates *HJ*, and ***HJ*6** completes the self-drive circuit for the junction hunter. When a free junction is found, relay *KA* operates, and at ***KA*1** disconnects the drive circuit. This same contact operates relay *KB* which, at ***KB*2**, extends battery from *YB* via relay *DD* to the + wire of the parent junction, thereby repeating the calling condition from the dependent U.A.X. Relay *DD* operates in series with the signalling relay at the parent exchange, and at ***DD*2** operates *DC*. ***DC*3** provides ringing tone to the caller.

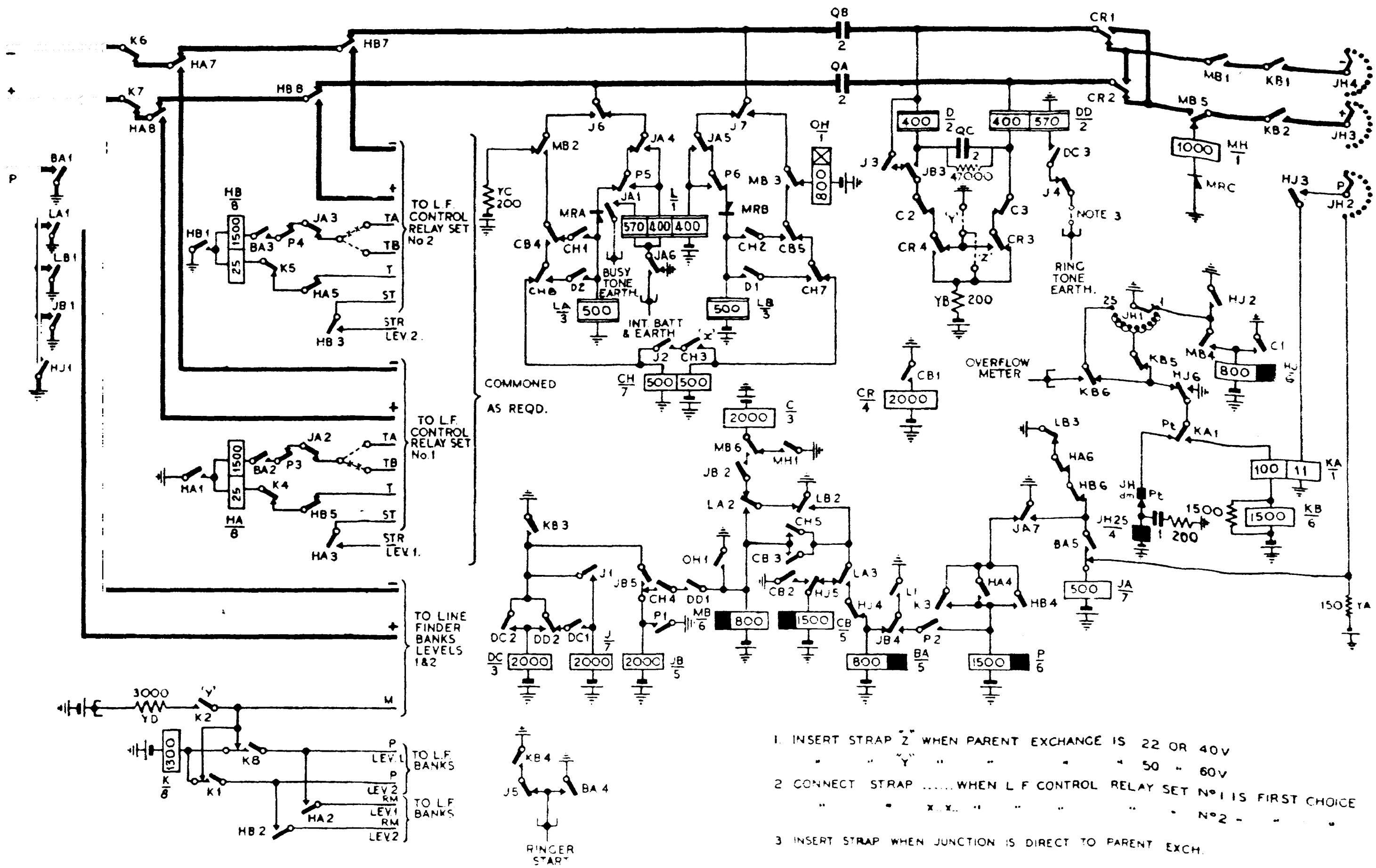


Fig. 462. Incoming Junction Circuit from Dependent U.A.X.

When the parent exchange operator inserts a plug in the answering jack, the + wire is disconnected and *DD* releases. *DD*2 operates *J*. ***J*3** applies earth to the — line of the parent junction, whilst ***J*4** disconnects ringing tone. ***J*6** disconnects relay *LA* from the + line of the dependent exchange junction, thus repeating the acknowledgment signal from the parent exchange back to the dependent U.A.X. When the acknowledgment signal is received at the dependent U.A.X., earth is applied to the — line to operate relay *CH* at the U.A.X. 13. ***CH*3** provides a holding circuit for *CH* for the duration of the call, whilst ***CH*1** re-establishes the circuit for relay *LA* to the battery on the + line. (The slug of relay *MB* allows the relay to remain operated during the release period of contact *LA*2.)

The application of battery to the — line of the parent junction causes the parent exchange equipment to re-establish the + line circuit, and hence to re-operate relay *DD*. ***DD*1** now completes a circuit for relay *JB*, which locks via ***JB*5**. ***JB*3** removes the battery condition from the — wire and inserts relay *D* in readiness to receive the supervisory condition from the parent exchange.

In due course the operator throws her speak key, and, by applying battery to the — wire, operates relay *D* at the U.A.X. 13. ***D*1** repeats the supervisory condition by returning battery via *LB* to the — wire of the dependent exchange junction. The following relays are now held: *CH, D, DC, DD, HJ, J, JB, KA, KB, LA, LB*, and *MB*.

If the call originates from a coin-box subscriber, the seizure condition from the dependent exchange is an earth on the — wire which operates relay *LB*. ***LB*2** operates relay *CB*, and ***CB*1** energizes relay *CR*. Contacts ***CB*4** and ***CB*5** re-arrange the connexions of the signalling relays, *LA* and *LB*, to cater for the revised signalling conditions from the dependent U.A.X. Similarly, contacts ***CR*1**, ***CR*2**, ***CR*3**, and ***CR*4** re-arrange the conditions on the parent exchange junction side of the circuit. The subsequent operations are similar to those described above, except that the appropriate coin-box signalling conditions are repeated at each stage. When the call is established for conversation, the following relays are energized: *CB, CH, CR, D, DC, DD, HJ, J, JB, KA, KB, LA, LB*, and *MB*.

Relay *MH* responds to the manual hold battery condition on the + wire of the junction from the parent exchange. If the plug is still in the answering jack when the calling subscriber clears, battery from *YC* is returned over the + wire of the junction to the dependent U.A.X. The circuit arrangements at the dependent exchange provide for the holding of the subscriber on receipt of this repetition of the manual hold signal. If the calling subscriber should recall during manual hold conditions, relay *OH* operates. ***OH*1** re-operates relay *MB*. Relays *C* and *MH* now release, relays *LA, LB, D*, and *DD* are re-operated, and supervisory conditions are extended to the parent exchange.

If an "0" level call is made from the dependent U.A.X. when all junctions between the U.A.X. 13 and the parent exchange are engaged, the junction hunter steps to the 25th bank contact. Relay *KA* now operates to the battery via relay *JA* and the 150 Ω resistor *YA* in parallel. ***KA*1** disconnects the drive circuit and operates relay *KB* as before. Relay *JA* also operates when the wipers reach the 25th contact, and at ***JA*1** applies busy tone to the 570 Ω winding of relay *L*. ***JA*2** and ***JA*3** disconnect the operate circuits of relays *HA* and *HB* whilst ***JA*4** and ***JA*5** disconnect relays *LA* and *LB* from the line and connect relay *L*. Busy tone and flash are now returned to the caller by contact ***JA*6**. Contact ***KB*6** operates the overflow meter.

Relay *L* operates to the calling conditions on the junction, and at ***L*1** operates relay *BA*. ***BA*5** disconnects the initial operating circuit of relay *JA* and provides an alternative circuit via ***JA*7**. The release of relay *LA* (by the operation of ***JA*4**) releases *MB* at *LA*2, and *MB*4 in restoring releases relay *HJ*. *HJ*6 now releases relays *KA* and *KB*, and *KB*6 completes a homing circuit for the junction hunter, which restores to normal. When the calling party clears, relay *L* releases, and *L*1 in turn releases *BA*. *BA*5 releases *JA*, and the circuit is now fully restored to receive further calls.

If a call to the U.A.X. 13 automatic equipment is required, the calling condition from the dependent exchange is a loop which operates relays *LA* and *LB*. ***LA*3** operates relay *BA*, and contacts ***BA*2** and ***BA*3** complete the testing-in circuit for the *HA* and *HB* relays. The call then proceeds via the linefinder and group selector as already described for previous circuits.

Outgoing Junction to Dependent Exchange. Fig. 463 shows a circuit suitable for use at a U.A.X. 13 on junctions outgoing to a dependent exchange. The arrangements are, in general, similar to those on junctions outgoing to a non-dependent exchange. The main difference is the provision of facilities for the repetition of the trunk offering signal. The low resistance + battery signal on the incoming junction from the parent route operates relay *TO* over the *M*-wire (via relay *DS* of the

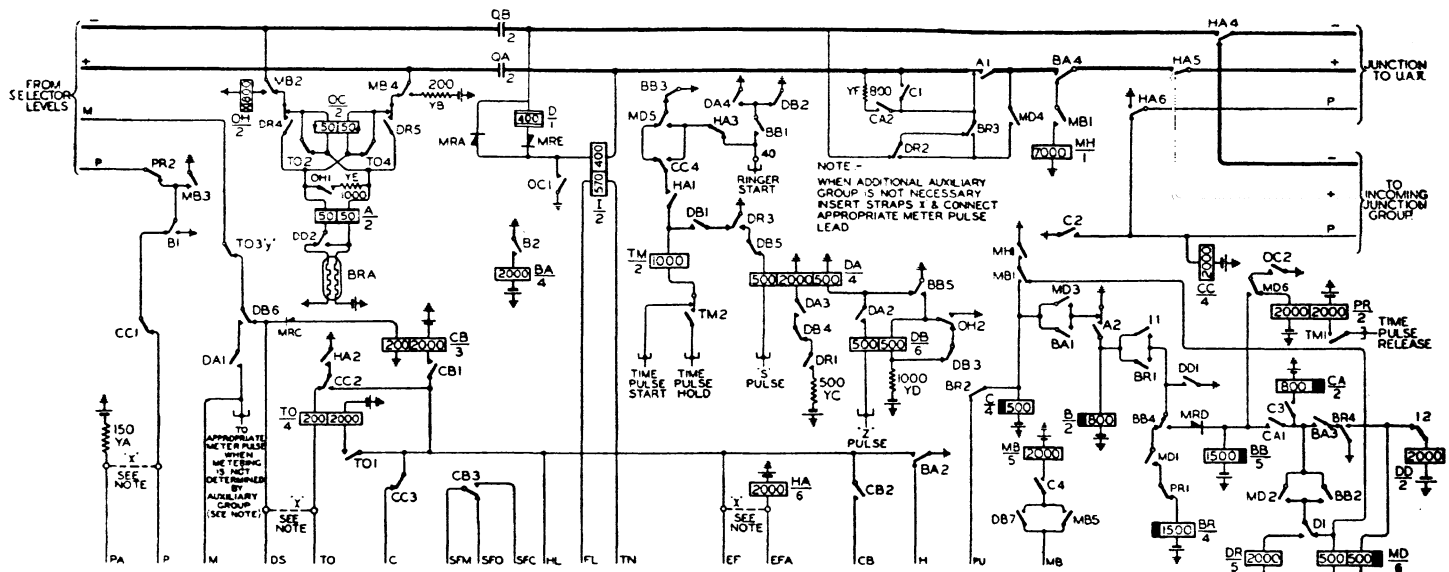


Fig. 463. Outgoing Junction to Dependent Exchange

auxiliary equipment). Contacts *TO2* and *TO4* switch in the *OC* relay which can then respond to earth signals on the junction loop. Application of an earth signal to the loop (i.e. during each operation of the ringing key at the parent exchange) operates relay *OC*. *OC1* repeats the earth signal forward to the dependent exchange.

parent exchange or from any other exchange where trunk offering facilities are provided. The operation of relay *TO* to the low resistance + potential on the *M*-wire not only switches in relay *OC* for trunk offering purposes, but also functions in the same way as relay *DS* of previous circuits to overcome any route restrictions.

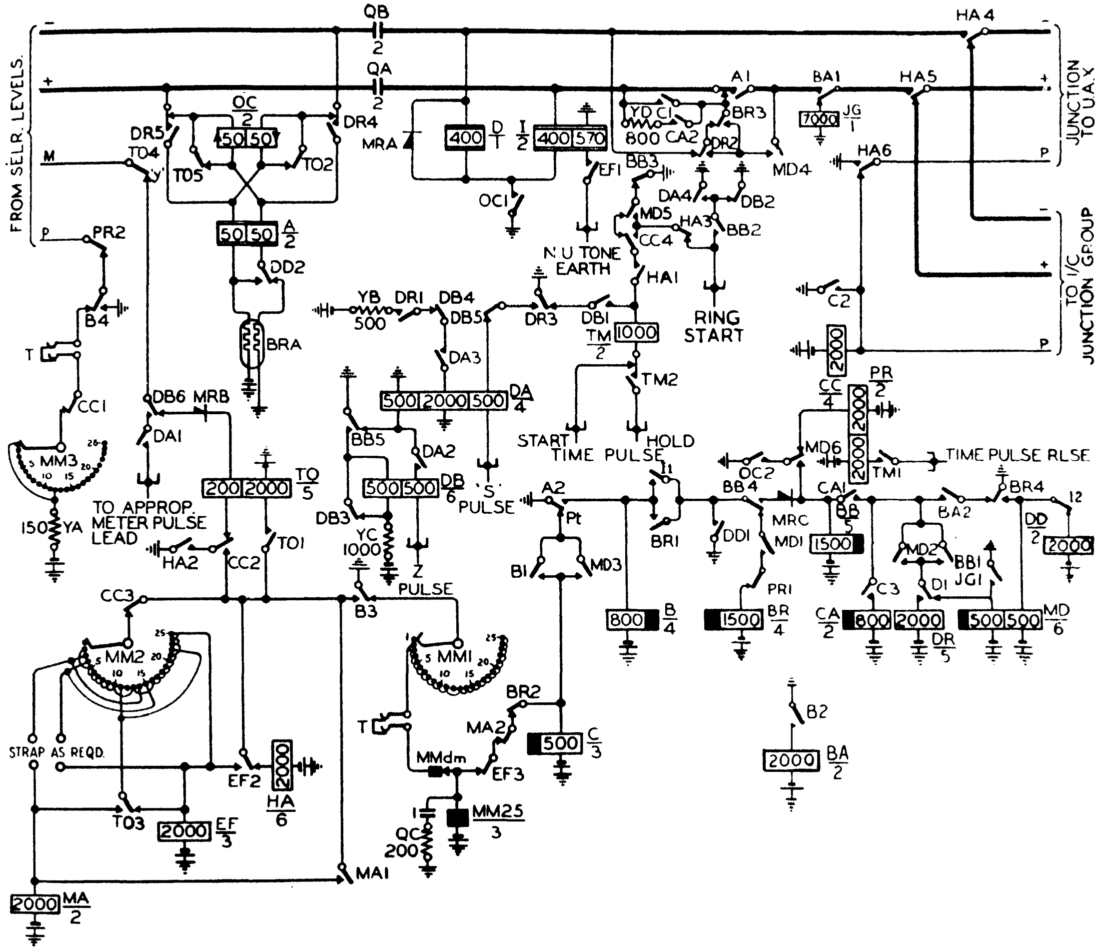


FIG. 464. OUTGOING JUNCTION TO DEPENDENT EXCHANGE—TERMINAL TRAFFIC ONLY

Fig. 464 shows another type of circuit which is used when all traffic terminates at the dependent U.A.X. The main feature of this circuit is the inclusion of a route restriction uniselector (*MM*). The impulse trains received from the subscriber are repeated to the *MM* uniselector magnet, and the banks of this uniselector are strapped so that access is barred to all outlets at the dependent exchange other than those to local subscribers. These restrictions are cancelled on calls from the

In all other respects Figs. 463 and 464 are substantially similar to the circuits already considered, and a detailed description is therefore unnecessary.

Ringing, Tone, Time Pulse, etc. Circuits. The common services of a U.A.X. 13 are provided by a pair of jacked-in relay sets mounted at the rear of the test panel on the C unit. One relay set provides the ringing, dial tone, ringing tone, and the meter pulses, and is illustrated in Fig. 465.

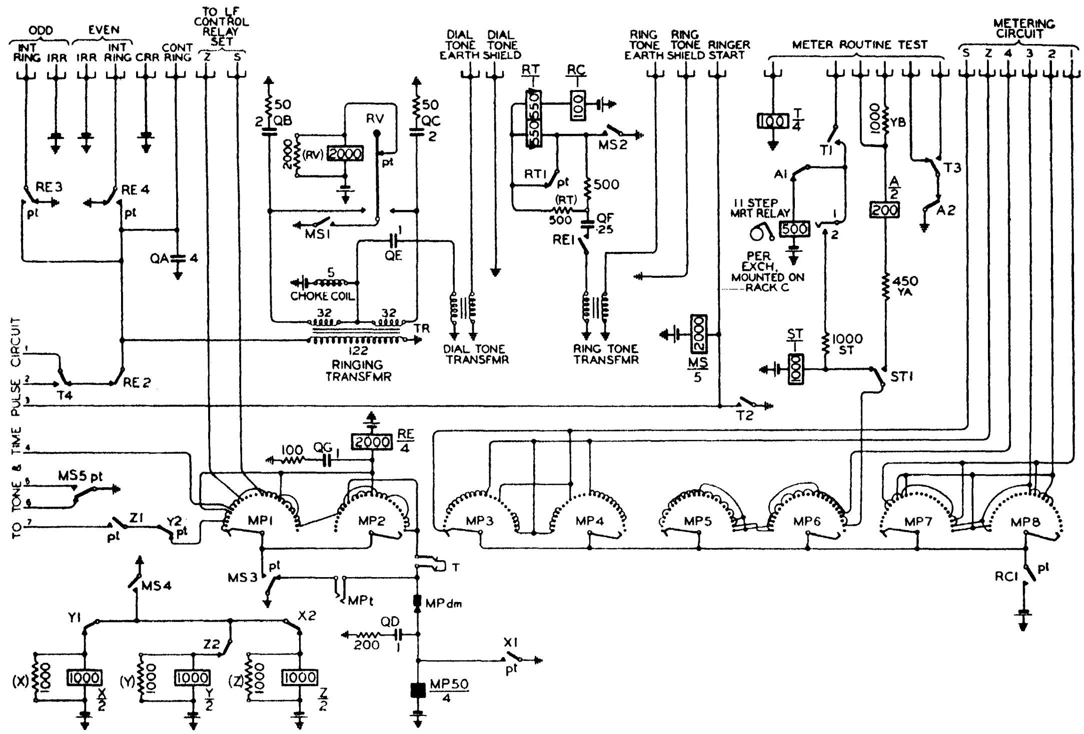


FIG. 465. RINGING AND METER PULSE RELAY SET

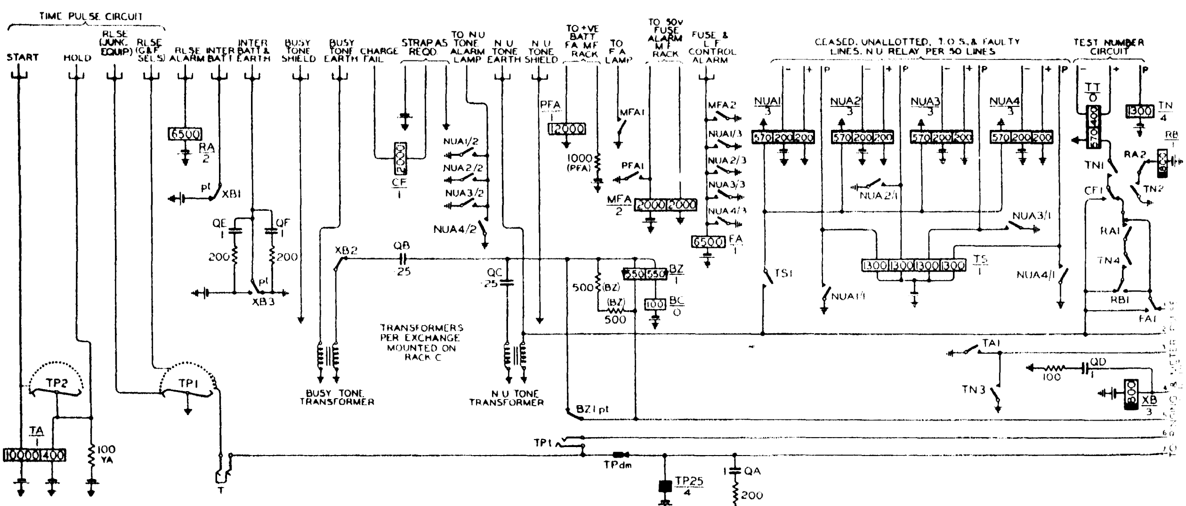


FIG. 466. TONE AND TIME PULSE RELAY SET

The second relay set (Fig. 466) is closely associated with the first, and provides busy tone, N.U. tone, the time pulse circuit for forced release, and several other miscellaneous circuits.

The ringing tone is generated by a vibrating relay (*RV*) via a suitable transformer. Dial tone is also provided on a frequency doubling basis from the ringing transformer. Ringing tone is generated by a separate vibrator and is again applied to the equipment via a common transformer. The meter pulses are generated by an 8-level uniselector which is stepped by pulses obtained from three interacting relays (*X*, *Y*, and *Z*). The banks of this uniselector are connected to give one, two, three, or four metering pulses as required, and the *S* and *Z* pulses which are necessary for the meter control circuit.

The meter pulse uniselector also provides pulses to the time pulse relay set for the stepping of the time pulse uniselector. This uniselector has two effective arcs, one for supplying the forced release conditions on group selectors and junctions, and the other for time pulse control. The tone and time pulse relay set also includes four N.U. tone circuits and the test number circuit.

The circuit arrangements of the various component elements are substantially similar to the arrangements at a U.A.X. 12. The latter have been fully described in Chapter XIV, and no further explanation is necessary.

U.A.X. Types Superseded by No. 13 Equipment. The standard U.A.X. 13 supersedes several other systems of similar capacity. Whilst the obsolescent exchanges are being gradually converted to the standard system, there is a number of exchanges of these earlier types still working, and a brief description of these systems is given in the following paragraphs.

U.A.X. No. 6. The U.A.X. 6 is a somewhat larger version of the U.A.X. 5 described in Chapter XIV. The No. 6 exchange has a capacity of up to 200 lines and is made up of 25-line units, so that eight such units can be installed in one exchange. The system employs a uniselector type linefinder and a 200-outlet 2-motion selector of the pre-2000 type. The subscribers' numbering range is 200–299 and 310–399, and the selector is so arranged that it absorbs an initial digit of 2 or 3 to give local discrimination. The subscribers dial "01" for the parent exchange operator, and two digit codes are used to give access to adjacent exchanges. Like the U.A.X. 5, the equipment does not provide tandem facilities, trunk offering facilities, or multi-metering facilities, but the selector is arranged to give automatic hunting over small P.B.X. groups. The tones are non-standard.

U.A.X. No. 8. The U.A.X. 8 is built up on somewhat different lines from the U.A.X.s 5 and 6. There are three types of cabinet, viz. a linefinder unit, an ordinary final selector unit, and a P.B.X. final selector unit. The linefinders are 50-point uniselectors, whilst the final selectors are of the 100-outlet pre-2000 type. Group selectors are introduced to give access to the outgoing junctions and to the two final selector groups of the exchange. The subscribers' numbering range is 200–399, whilst adjacent exchanges can be obtained by the dialling of a single code digit. Digit absorption is not used, and the subscriber can obtain access to the parent exchange operator by dialling "0." The U.A.X. 8 provides tandem switching facilities, but not trunk offering or multi-metering. The tones are non-standard.

U.A.X. No. 10. The U.A.X. 10 is of the Bypath type (Bypath system type QC). The exchange has a maximum capacity of 200 lines (including junctions), whilst the complete exchange is made up of 4 self-contained 50-line units. Large type uniselectors are used, both for the linefinders and for the selectors. A single linefinder stage is used in conjunction with a single switching stage to give access to any required number. The subscribers' numbering range is 200–399, which is obtained without the use of digit absorption. Provision is made for the dialling of the standard code "0" to obtain the attention of the parent exchange operator and also for the dialling of numbers on adjacent exchanges by the use of a single digit code. The U.A.X. 10 provides standard dialling facilities and P.B.X. facilities, but no trunk offering or multi-metering.

EXERCISES XV

1. Describe, with the aid of a suitable diagram, the main trunking features of a U.A.X. 13. How can this trunking scheme be amended to increase the capacity of the U.A.X. up to 400 lines maximum? In what circumstances is it possible to carry out such an extension?

2. Describe the construction and equipment of the three standard units of a U.A.X. 13. Give an approximate floor plan of a No. 13 exchange with a capacity for 150 lines and show the relative positions of the various units. What are the main cabling arrangements between the units?

3. A U.A.X. 13 is to be provided in an area where the number of subscribers at the date of opening is estimated to be 120. The subscribers' busy hour calling rate is 0·4 and the average holding time on calls of all types is 2·5 min. It is anticipated that 80 per cent of the originated traffic is to local subscribers, the remaining 20 per cent being routed over outgoing junctions to the parent and to other exchanges. It is calculated that the incoming terminal traffic to the U.A.X. during the busy hour is 1 T.U., whilst the tandem traffic through the U.A.X. during the same period is 2 T.U. Calculate the number of group selectors and final selectors required per A unit to give the standard grade of service.

4. Describe, with the aid of a suitable diagram, how the linefinder in a U.A.X. 13 is made to search for and seize a calling subscriber's line.

5. What happens in a U.A.X. 13 if:

(*a*) A subscriber lifts his receiver and then fails to dial?

(*b*) A subscriber dials the first digit of a local number and then waits for a prolonged period?

(*c*) A subscriber holds on after receiving N.U. tone as a result of dialling a barred code?

Illustrate your answer with simple sketches of the circuit elements concerned.

6. Describe the facilities provided in a U.A.X. 13 to minimize the danger of mutilation of the first impulse train received over an incoming junction.

7. When a U.A.X. 13 is used as a tandem dialling centre for distant exchanges, it is desirable to give access to outgoing dialling codes which are normally barred to local subscribers on the U.A.X. Give a simple diagram of the circuit arrangements which permit of the cancellation of route restrictions on interdialled calls.

8. Explain how the parent exchange operator can offer a trunk call to a subscriber on a U.A.X. 13 who is engaged on a local call. If the U.A.X. is not directly connected to the parent exchange, how are the trunk offering signals repeated at the intermediate point?

9. The equipment at a U.A.X. 13 provides multi-metering facilities so that ordinary subscribers on the U.A.X. can be permitted direct auto access to exchanges up to 15 miles radial distance. Coin-box subscribers, on the other hand, must be barred access to all junction routes which involve more than the unit-fee charge. Show how this differentiation is obtained if:

(*a*) The first outgoing junction link from the U.A.X. is to an exchange beyond 5 miles distance, and

(*b*) The objective exchange is within unit-fee radius but it is possible to obtain further exchanges in the multi-fee zone by tandem dialling.

10. If a U.A.X. is dependent upon a U.A.X. 13 for obtaining access to the parent manual board, it is necessary to provide facilities whereby a subscriber on the dependent exchange can obtain the attention of the parent operator by dialling a single digit "0." Show how such a call is routed through the U.A.X. 13.

CHAPTER XVI

THE UNIT AUTOMATIC EXCHANGE NO. 14

The U.A.X. 14 is the largest type of Unit Automatic Exchange. It is designed for use when the estimated subscribers' multiple will not exceed 800 lines at the 15-year period, and where the subscribers' busy hour originated traffic does not exceed 3·96 T.U. per 100 lines at the ultimate date. The equipment can be extended exceptionally to cater for a total of 1600 multiple if certain of the group selector levels are not required for outgoing junctions, but it is usually more economical to install standard non-director equipment where the anticipated growth exceeds the nominal 800 multiple. In certain circumstances, in fact, it is desirable to consider the installation of non-director equipment in preference to a U.A.X. 14 where the number of lines at the 15-year period exceeds, say, 600. The subscribers' busy hour calling rate, the amount of tandem traffic, and the extent of the multi-metering facilities required are important factors in such considerations.

The U.A.X. 14 employs 2000 type selectors with the standard 3000 and 600 type relays and battery testing circuits. Apart from the different trunking arrangements necessary to obtain the higher multiple capacity, the main distinguishing feature of the No. 14 equipment is the use of "open" type racks of similar design to the racks of the larger non-director and director exchanges. No attempt is made to enclose the units, but the U.A.X. building is provided with heating facilities under hygrostatic control.

Most of the apparatus racks are designed as "units" to meet the special requirements of the U.A.X., but some of the equipment racks are identical to those used in non-director and director exchanges.

U.A.X.s of the No. 12 and 13 type are usually installed by local labour, but the installation of the No. 14 type equipment is normally undertaken by the Telephone Contractors.

Facilities. The more important facilities provided by the U.A.X. 14 are:

(1) The subscribers' numbering range is

2000–2399
3000–3399

No. 3199 is reserved as the faults test number, and No. 3190 is the standard allocation for the service telephone. In some cases it is also desirable to reserve No. 2111 (for exchange line to test rack) and 3111 (additional service telephone). The Nos. 99 and 90 in the 3000's group and 90 in the 2000's group are used for routine testing and are therefore reserved for as long as possible.

(2) Up to five single-digit codes are available for outgoing junction routes (i.e. the digits 4–8). If more than this number of outgoing junction routes is required, level 8 is taken to 2nd selectors in order to provide ten 2-digit codes.

(3) The U.A.X. can be extended (exceptionally) up to 1600 multiple by avoiding the use of the single-digit codes 4–7 for outgoing junctions. The additional subscribers' numbering range is now

2400–2799
3400–3799

(4) A combined group of junctions is normally provided to carry the "9" and "0" level traffic to the parent centre. The first 2 junctions of this group are alternated on the group selector banks so that an alternative junction is taken up on a repetition call. In certain cases (i.e. where a large proportion of the traffic on the parent route is to the automatic equipment at the parent centre) it may be desirable to provide a separate auto route (usually from level 7) to the automatic equipment at the parent exchange. In general, a separate route can be justified when the total traffic to the parent exchange is more than about 7·5 T.U.

(5) The incoming junctions from the parent exchange and from the more important non-parent exchanges are terminated on individual selectors at the U.A.X. The smaller non-parent routes terminate on selector hunters which give access to a common group of 1st selectors.

(6) Incoming junctions from dependent exchanges are terminated on uniselectors which can be made to search either for a free group selector or for a disengaged parent junction as required, depending upon the differentiating signals received over the incoming junction. This facility of direct access to the parent route enables a subscriber on the dependent exchange to obtain the attention of the parent operator by dialling "0" once only.

(7) Facilities are provided for tandem dialling on any incoming junction route. As a matter of policy, a U.A.X. 14 is never made dependent upon any other U.A.X. for obtaining access to the parent manual board.

(8) Manual hold is provided on calls to the parent exchange from either ordinary or coin-box lines. The manual hold facility is also provided on calls from ordinary lines to non-parent manual boards (except where the call is routed through distant automatic equipment). Metering is not returned from manual boards which provide manual hold conditions.

(9) Facilities are provided for automatic metering of calls up to 4 units. The multi-metering equipment makes provision for the barring of all except unit-fee calls to coin-box subscribers, and for preventing dialling by ordinary subscribers beyond the range of the multi-metering equipment.

(10) If the U.A.X. is on the fringe of a director area, and the volume of traffic justifies the provision of direct junctions, it is possible to give direct access from the U.A.X. to director exchanges within unit-fee radius. It is the intention to design equipment for use in the future which will give more general access to a director network by the installation of special discriminating equipment which will cater for the large number of dialling codes required.

(11) Direct access from ordinary subscribers on a U.A.X. 14 to non-parent manual boards up to 20 miles distant is permitted. Dialling out by coin-box lines is not usually allowed.

(12) Trunk offering to local subscribers on the U.A.X. 14 is provided from the parent manual board, and, if required, from other non-parent manual exchanges.

(13) P.B.X.s of up to 10 lines can be accommodated throughout the multiple range of the U.A.X. A second type of final selector provides facilities for one P.B.X. of up to 20 lines in each 100's group with 2/10 facilities on the remaining lines. The large (up to 20 lines) P.B.X.s can be accommodated on any two levels in the same 100's group provided that the group does not commence with level 9.

(14) The equipment provides the standard system of tones. Dialling tone is given to a subscriber when he is connected to a 1st selector, and is returned to operators on all incoming junction calls (except those carrying 2 V.F. traffic). Ringing tone is given in accordance with the usual practice on calls to disengaged local subscribers and on junction calls to manual switchboards. N.U. tone is given if a spare line, or a spare or barred code, is dialled. N.U. tone is also given on the service telephone number of a U.A.X. 14 when the alarms are extended to the parent centre. Busy tone and flash are given if the caller dials an engaged line, or if there is congestion on the group selector level. Busy tone is also returned on incoming junction calls if dialling commences before a free selector has been seized. Similarly, on calls to local subscribers, busy tone is returned if the second numerical digit is dialled before the 1st selector has restored after receiving the first digit.

(15) Forced release from the common switching equipment is not provided. An urgent alarm is, however, given after a delay period of from 6 to 12 min if the number of P.G.s exceeds a predetermined figure.

(16) Provision is made for the installation of interception equipment where required.

(17) Equipment is provided to give service observation facilities.

(18) Overflow meters are provided to record congestion conditions on the group selector levels. A group occupancy meter is also provided per group of primary finders and per selector hunter group.

(19) Automatic traffic recorder equipment is available.

(20) Facilities are provided for the extension of urgent alarms to the parent centre.

Trunking Scheme. Fig. 467 shows the general trunking arrangements of a U.A.X. 14. The subscribers' lines are terminated on the banks of 100-outlet 2-motion type linefinders. Each group of 100 subscribers' lines is served by a maximum of 10 linefinders. Three of these linefinders are directly connected to 1st group selectors, whilst the remaining 7 are provided with selector hunters which give access to a common group of 1st selectors. This common group is available to both local subscribers and to all incoming junctions which are not terminated directly on 1st selectors. Normally, one control relay set is provided per linefinder group, but the groups are arranged in pairs so that, in the event of one control set becoming faulty, the control set of the second group automatically takes over the functions of the faulty relay set. This scheme is, of course, not practicable where there is an odd number of groups. In these circumstances the odd group is provided with two control relay sets so that service will be maintained in the event of one control set becoming faulty. Coin-box lines may be allocated to any position on the linefinder banks, facilities being provided for a discriminating signal by suitable connexions to an additional bank of the linefinder.

It has been seen that the U.A.X. 14 employs a 4-digit numbering scheme, the initial digit of all subscribers' lines being either 2 or 3. The initial digit is used for discrimination purposes, and is absorbed by the 1st group selector. Levels 1, 2, 3, and 0 of the 1st selector banks are trunked to

4 groups of 200-line final selectors. Level 1 gives access to subscribers' group 2100–2199 and 3100–3199. Similarly, level 2 gives access to subscribers' numbers 2200–2299 and 3200–3299 and so on. When the 1st group selector absorbs the initial digit (i.e. 2 or 3), a discriminating signal is passed forward to the final selector to effect wiper switching either to the upper or to the lower bank of the final selector multiple, thereby selecting either the 2 or the 3 group as required. This "pairing" principle has two important advantages:

(*a*) Only 4 levels of the group selector are required to give access to 8 groups each of 100 lines. The 4 levels saved are available for outgoing junction routes.

(*b*) Only 4 groups of trunks are required between the group selectors and the final selectors instead of 8. This increases the trunking efficiency by concentrating the traffic into a smaller number of groups with a larger number of circuits per group (see Chapter II).

The final selectors are of the 200-outlet type with a wiper switching relay to receive the discriminating signal from the 1st group selector. As in the U.A.X. 13, the final selector is provided with facilities for the offering of trunk calls by the parent exchange operator to an engaged subscriber. There are two types of final selector: one type caters for single lines and for P.B.X.s of up to 10 lines; the second type of final selector gives facilities for one or two P.B.X. subscribers of up to 20 lines, the remaining multiple being available for ordinary and 2/10 P.B.X. lines.

The outgoing junctions to the parent exchange are trunked from level 9 of the 1st group selectors. If the caller dials "9," the appropriate signals are transmitted over the parent route to direct the call to the automatic equipment at the parent exchange. If the digit "0" is dialled, the group selector is again stepped to level 9, and the last impulse is used to operate discriminating relays. The "0" level discriminating signal is passed forward to the outgoing junction relay set where the necessary conditions are set up to route the call to the parent manual board. Coin-box discrimination is also provided so that calls from a coin-box subscriber appear on a special calling lamp at the parent switchboard. Levels 4 to 8 of the 1st group selectors are available for outgoing junction routes (other than to the parent exchange). If the number of junction codes exceeds 5, it is necessary to employ 2nd group selectors.

The junctions from the parent exchange terminate on individual 1st group selectors. Incoming junctions from adjacent non-parent exchanges are given access to the common group of 1st selectors via selector hunters. Junctions from dependent exchanges are provided with special terminations which include a uniselector which functions as a combined selector or parent junction hunter as required. If the signalling conditions from the dependent exchange indicate that the call is to be routed to the parent manual board, the uniselector behaves as a junction hunter to select a free circuit to the parent exchange. If, on the other hand, the signalling conditions from the dependent exchange indicate that the call is to be routed through group selectors at the U.A.X. 14 (i.e. tandem calls or calls to local U.A.X. 14 subscribers), the uniselector performs as a selector hunter, and extends the junction to a free 1st selector. All junctions may be either bothway, as shown in Fig. 467, or may be split to form unidirectional circuits, the particular arrangements adopted at

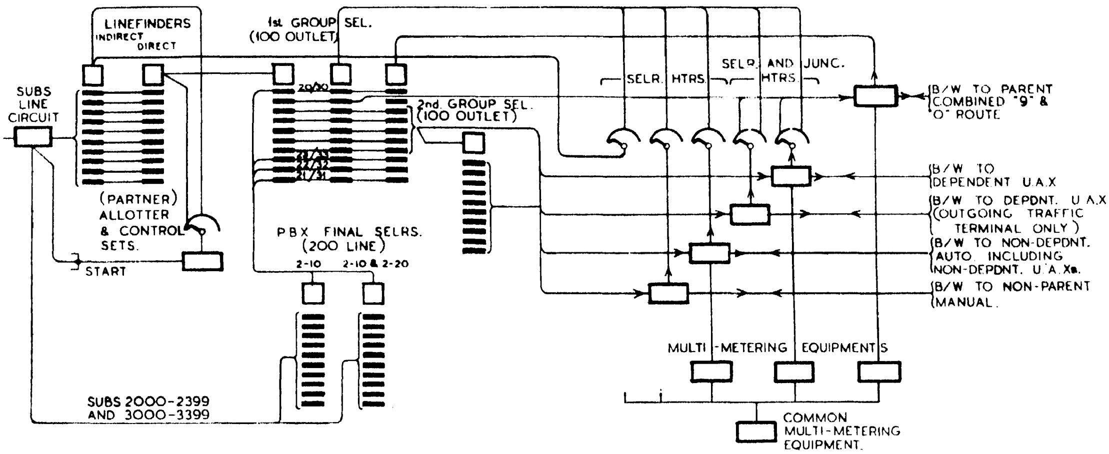


FIG. 467. TRUNKING ARRANGEMENTS OF A U.A.X. NO. 14

any given exchange depending upon the traffic conditions at that exchange.

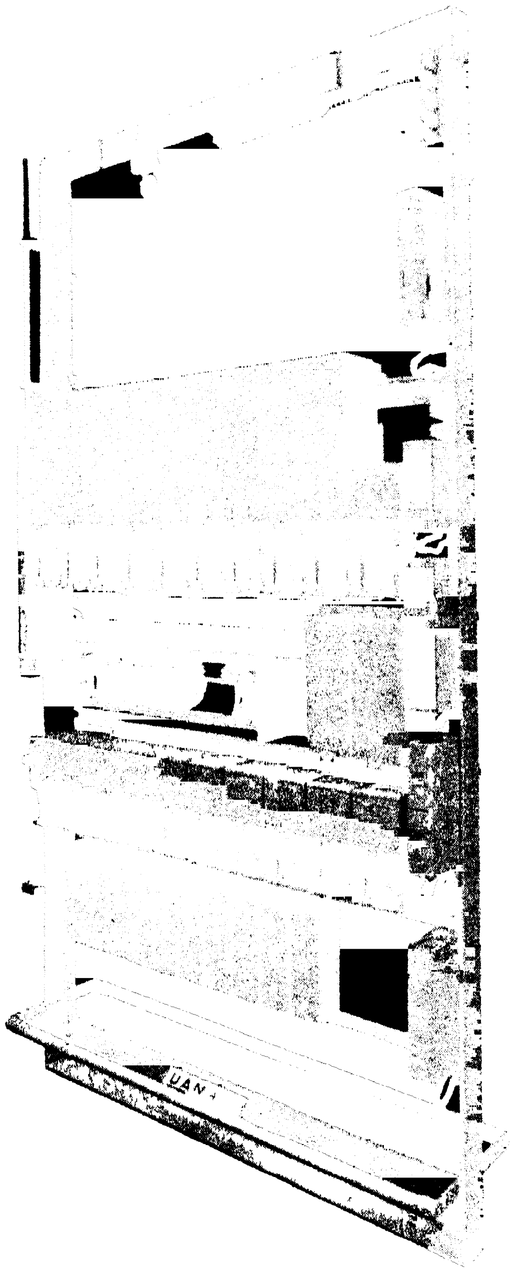


FIG. 468. FRONT VIEW OF UNIT NO. 14A

If an outgoing junction route carries traffic of differing call values, multi-metering equipment is associated with the outgoing junction relay sets. This multi-metering equipment contains the necessary apparatus for the determination of the fee from the routing digits dialled by the subscriber. It also provides facilities for barring access from coin-box subscribers on multi-fee routes, and from ordinary subscribers to exchanges beyond the range of the multi-metering equipment. If the number of codes exceeds the capacity of the individual multi-metering relay sets, then it is necessary to provide common multi-metering equipment to extend the number of codes.

The 1st selectors which serve the various selector hunters (both subscribers and junction) are provided with a group control circuit, so that the selector hunters are prevented from rotating continuously when all the selectors in the group are engaged.

Standard Units. The No. 14 exchange is built up of the required number of five standard units together with certain miscellaneous racks. The units are designated and equipped as follows:

Linefinder and final selector unit .	Code 14A
Group selector unit	Code 14B
Junction equipment unit . . .	Code 14C
Miscellaneous unit	Code 14D
Auxiliary equipment for interdialling with director areas . . .	Code 14E

In addition to the specially designed units, certain standard apparatus racks are also required. These are:

Meter rack
Meter pulse machine rack
Traffic recorder rack
Test rack
Trunk distribution frame
Combined M and I.D.F.

All racks and units are 8 ft $6\frac{1}{2}$ in. high. The A and B units are 4 ft 6 in. wide, whilst the C, D, and E units, the meter rack, and the meter pulse machine rack are 2 ft 9 in. wide. The test rack and traffic recorder rack are 1 ft 6 in. wide, whilst the trunk distribution frame has the usual width of 2 ft 3 in.

Unit No. 14A. This unit, which is illustrated in Fig. 468, accommodates the subscribers' line relays, the linefinders, selector hunters, allotters, control relay sets, final selectors, and the miscellaneous equipment (including the group control and the linefinder test equipment). The apparatus is mounted on four shelves as follows:

Shelf D provides a capacity for 10 final selectors, including the test final selector. One test final selector is fitted per pair of A units.

Shelf C provides a capacity for 7 selector hunters and 2 allotters together with 2 control relay sets.

Shelf B has a capacity and banks for ten 100-point linefinders.

Shelf A is wired for 100 subscribers' calling equipments including up to 15 coin-box lines.

Sufficient space exists above shelf D for the fitting of an additional shelf of final selectors if the traffic is in excess of the capacity of the normal 10 selectors.

Unit No. 14B. This unit accommodates 1st and/or 2nd group selectors and the associated miscellaneous equipment. The selectors are mounted on five shelves, each of 10 selectors, with multiple connexion strips at the rear of each shelf. In order to avoid the provision of unnecessary equipment, the group selectors, the selector banks, and the associated shelf equipment, are provided as individual items, and the number of shelves fitted in any particular case is dependent upon the trunking arrangements of the exchange. The shelf jack wiring is arranged so that any shelf can be used either for 1st or 2nd group selectors, as required.

The general appearance of the B unit is similar to that of a group selector rack in a standard non-director exchange, which has already been illustrated in Fig. 154.

Unit No. 14C. This unit accommodates the relays, uniselectors, etc., which are required for the junction terminations. The circuits are strip mounted on standard flanged type mounting plates, and, when the amount of apparatus necessitates the use of more than one mounting, two or more plates are bolted together to form a complete assembly. The plates are interconnected by means of a local form, and all the external connexions are terminated on connexion strips mounted behind the plate. A test jack is fitted on each equipment, and access is given to it without removing the relay plate covers. The drillings on the C unit are of a universal character, so that junction units of various size can be fitted in any desired position on the rack.

The equipment of the C unit does, of course, vary with the type of junction terminations to be accommodated. Fig. 469 shows a typical arrangement (in the more recent exchanges the selector hunters are placed in a lower position to facilitate the tracing of calls).

Unit No. 14D. This unit accommodates the following miscellaneous equipment:

Shelf G. 1 service observation equipment.

Shelf F. 4 test and plugging up circuits.

Shelf E. 4 changed number equipments and 1 (6 sec) alarm delay equipment.

Shelf D. 1 service interception finder, 1 howler and the P.G. milliammeter.

Shelf C. 4 N.U. tone relay sets.

Shelf B. 1 test number, 3 service interception and 1 alarm extension relay set.

Shelf A. 1 test selector, 3 alarm delay relay sets and 1 howler relay set.

The three lower shelves are arranged for "jacked-in" units. The service observation equipment is assembled on the strip mounted principle, but the mounting plates are bolted together to form a complete unit which can be readily mounted on the rack.

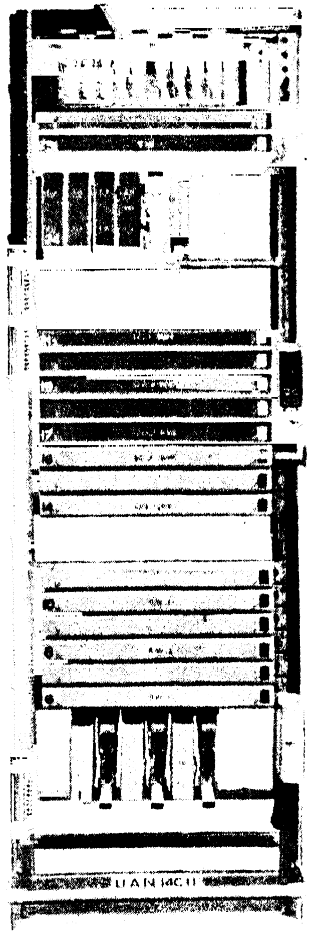


FIG. 469. UNIT NO. 14C WITH TYPICAL EQUIPMENT

Unit No. 14E. It is the intention to fit this unit only at exchanges which have access to a number of exchanges in a nearby director area. The E unit contains various relay sets and 2-motion

selectors, together with a translation field. The circuit arrangements are somewhat similar to the *BC* selector in a director exchange. The apparatus is mounted on 8 shelves as follows:

Shelves C to H have a capacity for 30 route discriminating relay sets.

Shelf B provides for a maximum of 5 common route discriminating relay sets.

Shelf A provides for up to 5 route discriminating selectors. These selectors are of the 8-level 2-motion type.

The translation fields of the 5 selectors are fixed to a common framework which is mounted across the unit. The bank contacts of the selectors are permanently wired to the connexion strips on the translation field, and the design is such that

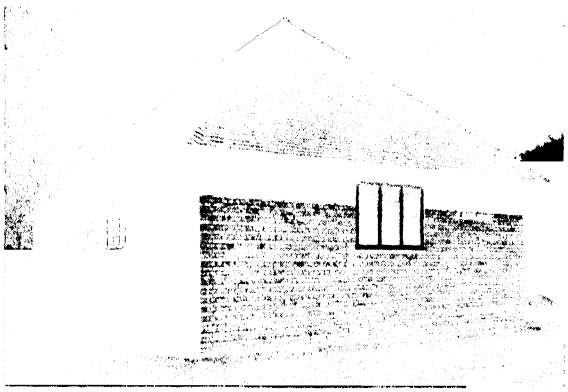


FIG. 470. STANDARD BUILDING TYPE D

the appropriate meter-fee connexion can be obtained by jumpering and commoning between jacks.

Lay-out of Equipment. The buildings for U.A.X.s 14 are of standardized design. There are six alternative arrangements depending upon the shape of the site, the ultimate capacity of the exchange, and so on. The main differences between the alternative designs are:

Type D Building. This building has internal dimensions 63 ft × 24 ft 6 in., and is used when it is estimated that the 15-year development is between 401 and 600 subscribers' lines. This is perhaps the most common type of building, and is illustrated in Fig. 470. With buildings of this type it is usual to provide a site 50 ft × 85 ft.

Type D1 Building. This building is similar to type D, but the staff room, lavatory, and store-room are at the side instead of at the rear of the building. This design requires a site of the order of 60 ft × 85 ft.

Type E Building. This building is used for somewhat larger exchanges, i.e. where the 15-year

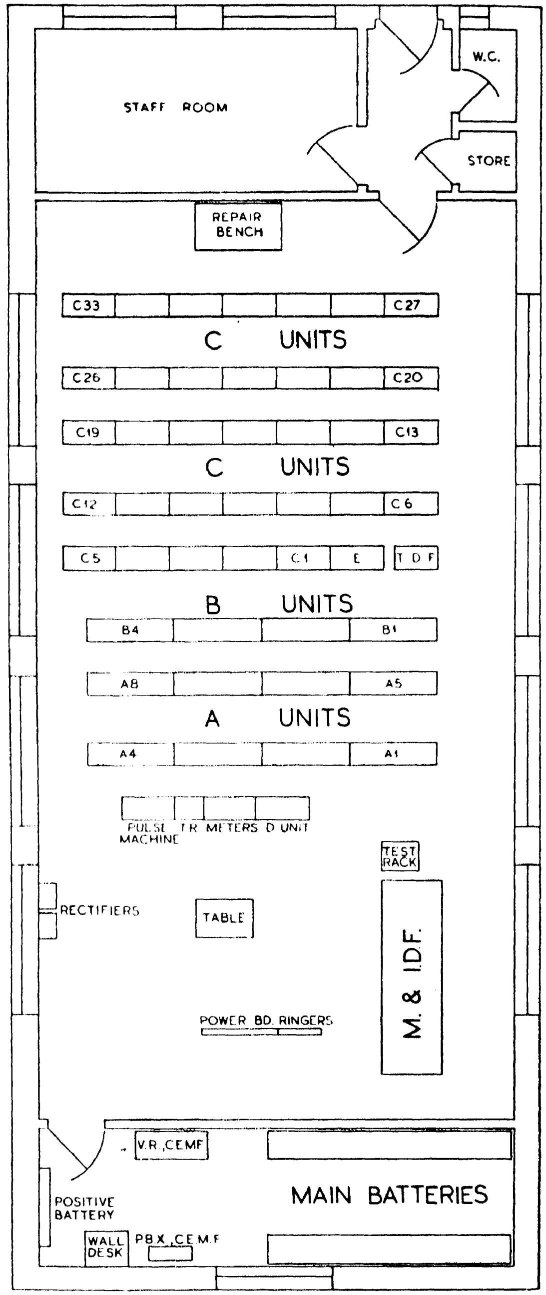


FIG. 471. TYPICAL LAY-OUT OF APPARATUS OF A U.A.X. 14 IN A D-TYPE BUILDING

development forecast is between 601 and 800 subscribers' lines. The internal dimensions are similar to the D1 type, but the building is designed

so that another floor can be added to cater for growth. The approximate site dimensions are 50 ft × 85 ft.

Type F Building. This design is an alternative to type E, with provision for lateral instead of vertical extension. Generally speaking, it is preferable to adopt the type F building where there is adequate space on the site, since it is less costly than the E type of building with its vertical extension. The approximate site area required is 70 ft × 120 ft.

Type G1 Building. This is a smaller design for use when the estimated 15-year requirements are less than 400 subscribers' lines. The internal dimensions are similar to the D type.

Type G2 Building. This is an alternative to the G1 design and is suitable for use when the building is sited parallel to the frontage. The G1 design is intended for erection at right angles to the frontage of the site.

Buildings type D, D1, E, and F can all accommodate an ultimate subscribers' multiple of 800. The buildings are usually of brick construction with cavity walls, and are lined with "Insul" wood or similar boarding to minimize heat dissipation.

Fig. 471 shows the lay-out of apparatus in a D type building. The lay-out follows standard non-director practice with the usual spacing between suites of racks. A fully equipped exchange to serve 800 subscribers requires the following units and racks:

Fig. 472. General View of a U.A.X. 14—Looking Towards M.D.F.

8 A units (1 per 100 lines).

1–4 B units (depending largely upon the volume of junction traffic).

Up to 33 C units (again depending upon the number of junctions).

1 D unit.

1 or 2 E units (only at exchanges which have access to a number of exchanges in an adjacent director area).

1 meter rack.

1 meter pulse machine rack.

1 or 2 trunk distribution frames.

1 traffic recorder rack (plus separate access rack in large exchanges).

1 test rack (provided only when there are more than 500 lines).

1 combined M. and I.D.F.

1 power switchboard, ringers, rectifiers, batteries, etc.

modates 40 meters, and the whole rack has a capacity for 800 subscribers' meters and some 80 traffic meters. The D unit occupies the right-hand position of the miscellaneous suite. The P.G. milliammeter will be noted above the various miscellaneous relay sets.

The cabling between racks and to the I.D.F. is carried out on open type cable runways of similar

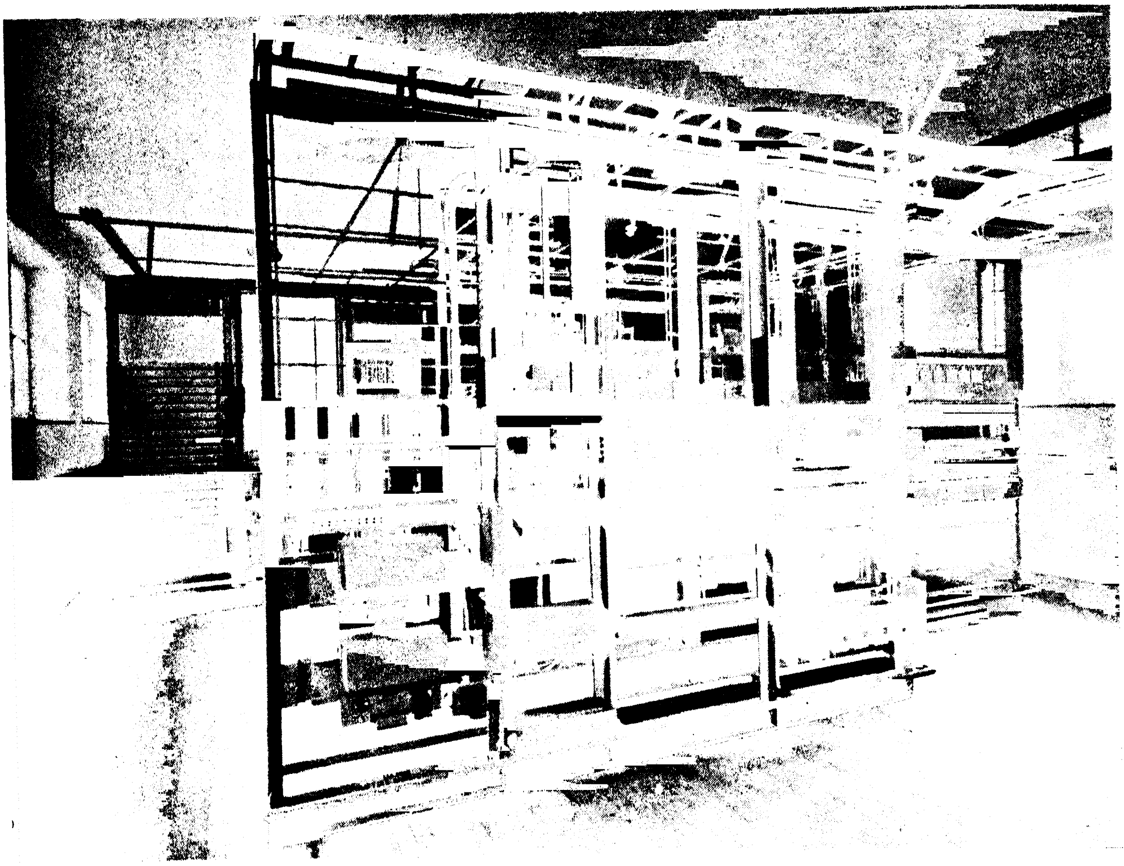


FIG. 473. GENERAL VIEW OF EQUIPMENT—MISCELLANEOUS RACKS IN FOREGROUND

Fig. 472 gives a general view of a partly-equipped exchange. The C units, with their strip mounted junction equipment, will be seen in the left foreground, and the A units occupy the centre position. The most distant suite is a rear view of the miscellaneous racks. This suite is shown more clearly in Fig. 473. The left-hand unit is the rack which contains 2 meter pulse machines and the various distribution jacks and fuses which are associated with the supply of meter pulses to the exchange. The traffic recorder is to the right of this rack, and is followed by the meter rack. The meters are mounted on plates, each of which accom-

construction to those used in larger exchanges. The relative humidity is controlled by tubular heaters which are fitted at the foot of each rack immediately below the wiring (see Fig. 472).

The cabling arrangements are much the same as those of a non-director main exchange. The subscribers' circuits terminate on the line side of the M.D.F. where they are cross-jumpered to the appropriate numerical position on the exchange side. The circuits are then cabled from the exchange side of the M.D.F. to the multiple side of the I.D.F., at which point the meters are associated. Each line can then be allocated to any

desired calling position by cross-jumpering on the I.D.F. to the appropriate linefinder termination on the local side. The linefinders themselves are wired to the multiple side, from which they can be jumpered to the local side and thence via cabling to 1st group selectors. The trunks from the 1st group selectors are cabled to the T.D.F. where they are graded as required before being extended to 2nd group selectors or final selectors. The junction groups are all terminated on the I.D.F. where they can be cross-jumpered to the various selector levels and junction pairs as necessary.

Linefinder and Associated Circuits. Fig. 474 shows the complete circuit arrangements of the subscribers' line relays, the linefinder, and the associated control circuits. The complete diagram may be considered as comprising:

The subscribers' line circuit.
The control circuit.
The allotter.
The linefinder.
The selector hunters.
The group control circuit.
The control re-set circuit.
A routine test circuit.

The operation of these various components is considered in the following paragraphs, but in the meantime it is desirable to review the main facilities provided by the equipment. These are:

(1) A maximum of 100 subscribers' lines can be served by the linefinder group.

(2) Any line circuit can be used for coin-box subscribers by the provision of a resistor and the wiring out of the coin-box discrimination lead.

(3) Three linefinders in each group are directly connected to 1st selectors, whilst up to a maximum of 7 further linefinders can be indirectly connected to 1st group selectors via selector hunters.

(4) Provision is made for the pre-operation of the group selector during the search for and seizure of a calling line.

(5) Although there is normally only one allotter control relay set per linefinder group, provision is made for 2 linefinder units to work as partners. The circuit arrangements are such that, if one control set is faulty, the control circuit of the partner unit takes over the work of the faulty relay set. If there is an odd number of units, it is usual to provide 2 control relay sets each serving 50 subscribers. The 2 relay sets work as partners under fault conditions.

(6) A faulty control set is locked out of service automatically, and an alarm is given, but should the second (partner) control circuit also fail whilst the first is out of service, both control circuits are returned to service.

(7) Directly-connected linefinders are taken into use when available, but when all directly-connected linefinders are engaged, the indirectly-connected linefinders are opened up for service.

(8) The allotter pre-selects a free directly-connected linefinder if one is available. If all directly-connected linefinders are engaged, the allotter steps to its first contacts in readiness for a full search over all linefinders should any directly-connected linefinder be available when the next call matures.

(9) A group-occupancy time metering circuit is provided to record the total period when congestion conditions exist on the linefinder group.

(10) The circuit provides for automatic routining of the control relay sets, allotters, and linefinders. Whilst one control set is in use for routine testing, the partner control circuit is made available for ordinary traffic.

(11) Facilities are provided for the recording of traffic on any or all of the linefinders in the group.

Seizure of Calling Line by Directly-connected Linefinder. Fig. 475 shows the circuit details involved when a linefinder searches for a calling line and switches the line through to a 1st selector. Let it be assumed that the wipers of the allotter are standing on the bank contacts associated with a disengaged directly-connected finder, and that the caller's line is connected to level 5 of the linefinder multiple.

When the calling subscriber lifts his receiver, relay *L* operates and at ***L*3** places a marking battery on level 5 of the vertical marking bank (*VMB*) of the linefinder. At the same time, ***L*1** marks the caller's rotary position in that level by connecting the appropriate *T* bank contact to the other side of level 5 of the vertical marking bank. ***L*2** busies the line on the final selector multiple, whilst ***L*4** sends a start signal to the control set to operate relay *S*.

The disengaged condition of the group selector is indicated by a battery potential on the *P*-wire, and this battery is extended via arcs 2 and 1 of the allotter switch to operate relay *HX* in the control circuit. ***HX*1** now completes a circuit for the *TR* relay via ***S*1**. ***TR*8** disconnects the allotter driving magnet circuit to prevent any stepping of the allotter whilst the linefinder is searching for the calling line.

The vertical testing relay *VT* is now connected via ***TR*1** and arc 3 of the allotter bank to one wiper

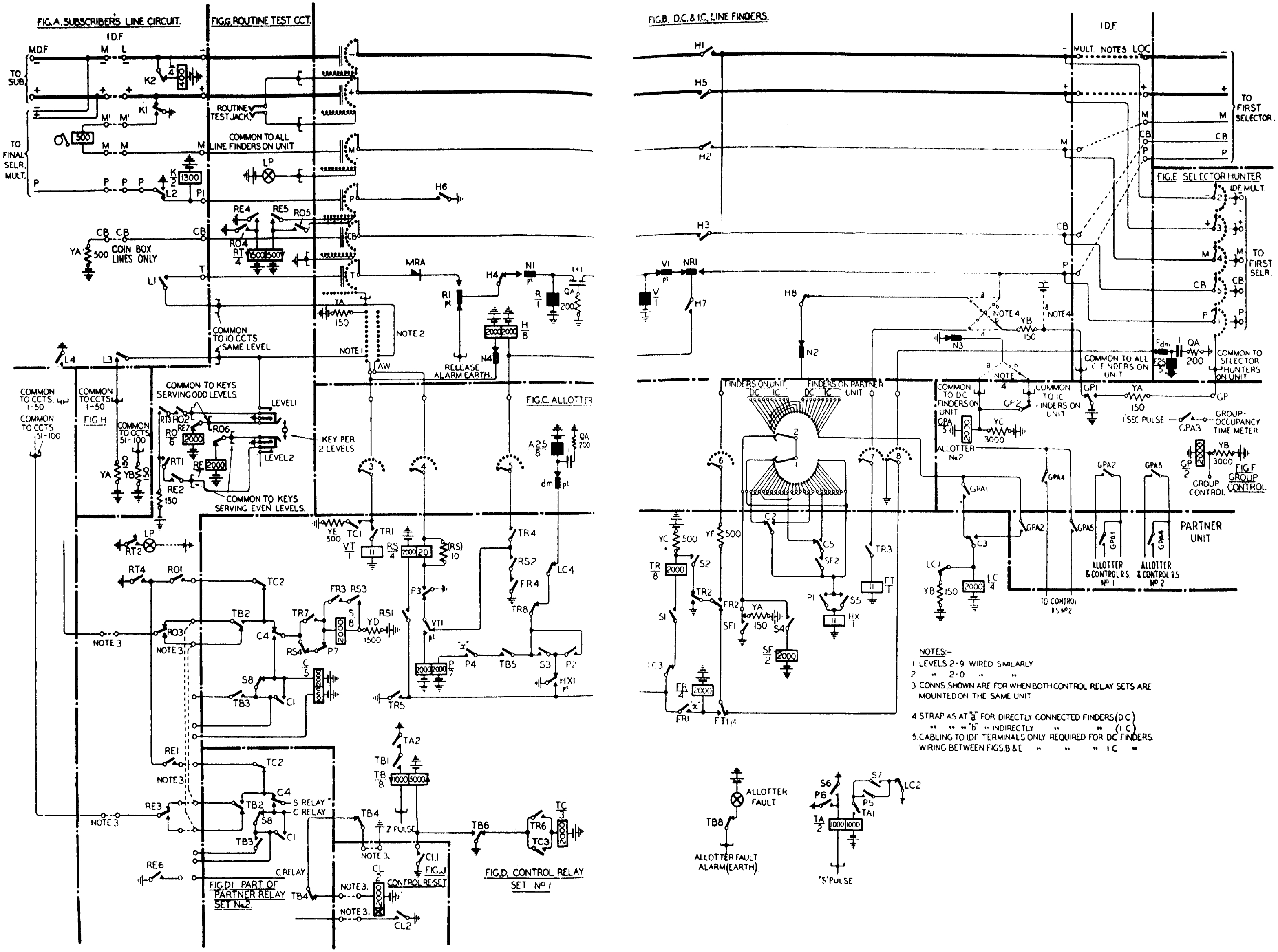


Fig. 474. Subscribers' Line Relays, Line Finders, and Associated Control Circuits

of the vertical marking bank. The *FT* relay is also energized to the battery in the linefinder circuit via ***TR*3** and arc 7 of the allotter. (The use of relay *FT* will be seen later when calls via indirectly-connected finders are considered.) The operation of the allotter. A circuit is now completed for the linefinder vertical magnet from the same earth, and the wiper carriage of the linefinder is stepped vertically under self-interrupted drive at *V*1. At the first vertical step, the *HX* relay of

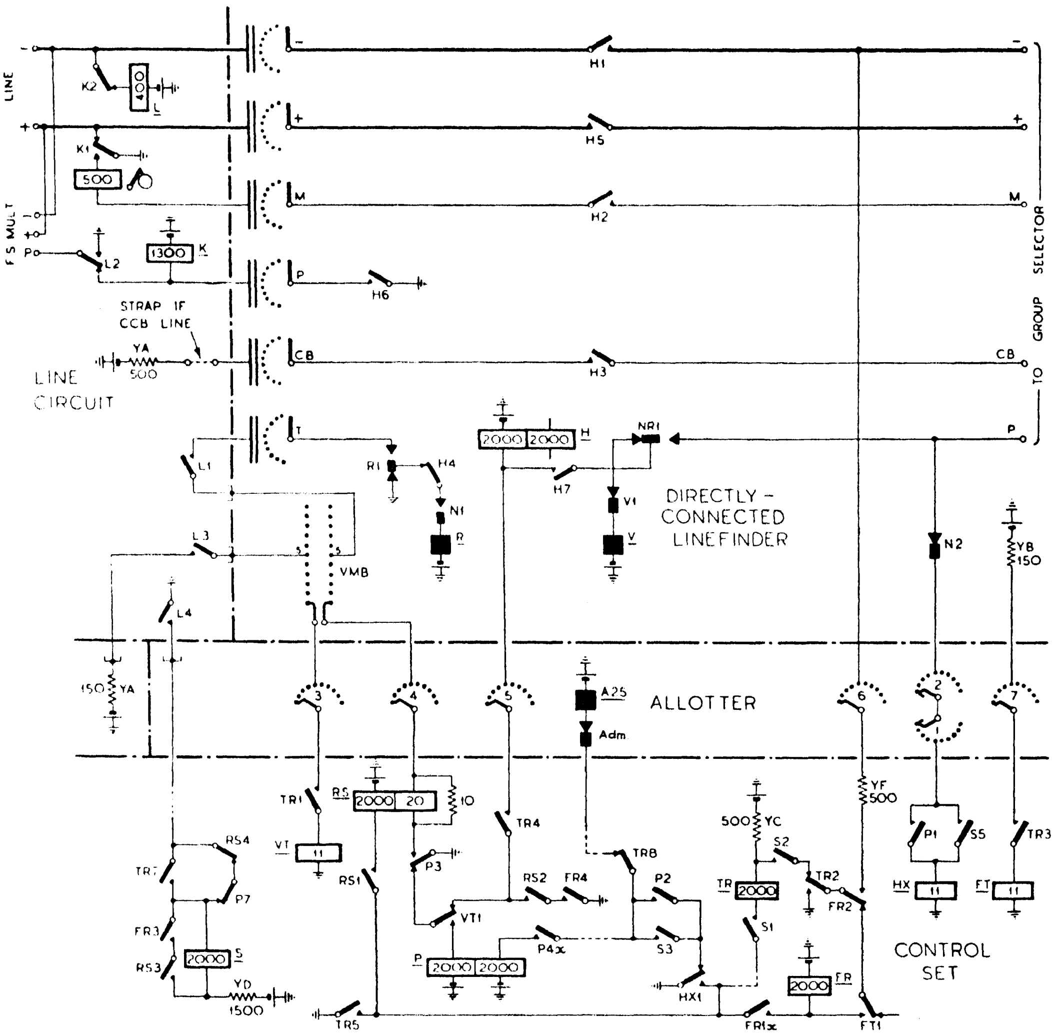


FIG. 475. ELEMENTS OF LINEFINDER CIRCUIT CONCERNED WITH THE SEARCH FOR A SUBSCRIBER'S LINE AND THE SWITCHING OF THE LINE TO A DIRECTLY-CONNECTED 1ST SELECTOR

FT*1** completes a circuit for relay *FR* which locks at its own contact (FR*1*x***).

A circuit is now completed for the pre-operation of the group selector *A* relay by extending earth from ***TR*2** via ***FR*2**, arc 6 of the allotter, to the negative wire of the linefinder. The switching relay (*H*) of the linefinder is also pre-operated from the earth at *P*3 via arc 5 of the control set releases due to the operation of contacts ***N*2**.

In due course the linefinder reaches the marked level, when relay *VT* operates to the marking battery extended by the ***L*3** contact of the subscriber's line relay. The vertical drive circuit is now broken at ***VT*1** and relay *H* is released by this same contact. The earth at *P*3 is extended

by ***VT*1** to operate relay *P*. *P* holds on its second winding from the earth at *HX*1.

The release of relay *H* (when *VT* operates) completes a circuit at *H*4 for the self-interrupted rotary drive of the linefinder. At each operation of the ***R*1** springs the *R* magnet battery is extended to the *T* wiper and, when the linefinder reaches the marked contact, relay *RS* operates to this battery and the earth at ***P*3**. ***RS*2** re-operates relay *H* to the earth at ***FR*4**, whilst contact ***H*4** in turn disconnects the rotary drive circuit. Relay *H* now holds via the rotary off-normal springs (***NR*1**) to the earth which has been returned on the *P*-wire as a result of the pre-operation of relay *A* in the 1st selector. The remaining contacts of relay *H* switch through the speaking pair, metering wire and coin-box discrimination wire to the 1st selector, and also operate relay *K* in the subscriber's line circuit.

The operation of *K* disconnects relay *L* and prepares the circuit of the subscriber's meter. The release of *L* in turn extends the guarding earth from contact ***H*6** to the final selector multiple and disconnects the start and marking conditions.

It has been seen that relay *RS* operates when the linefinder wipers reach the calling line. ***RS*3** applies a short circuit across the *S* relay coil. This makes the *S* relay slow-to-release, but, when its contacts do eventually restore, the *TR* relay is disconnected and the release of *TR*5 in turn releases relays *RS* and *FR*. Contact *TR*3 releases the *FT* relay. The *VT* relay also releases due to the disconnexion of the marking battery from the subscriber's line circuit.

Only the *P* relay in the control set is now operated, and immediately on the release of *TR*8 a circuit is completed for the allotter driving magnet to the earth at *HX*1. The allotter switch now drives under the control of its own interrupter contacts.

If a directly-connected linefinder is available, the *HX* relay in the control set operates to the free battery on the *P*-wire and cuts the allotter drive at ***HX*1**. This same contact also disconnects the holding circuit of relay *P*, and *P*1 in turn releases the *HX* relay. The allotter is now standing on a disengaged directly-connected finder which will be used for the next call. All relays of the control set (apart from certain fault control relays described later) are now normal.

The Use of Indirectly-connected Linefinders. Fig. 476 shows the connexions of an indirectly-connected linefinder. Each A unit has 3 directly-connected linefinders and 7 indirectly-connected finders. The indirectly-connected finders are brought into use only when all the directly-connected finders are engaged.

It has been seen that relay *P* is operated whilst the allotter is stepping after the completion of a call. If there is no congestion and the allotter fails to find a free directly-connected linefinder, it drives until it reaches contact No. 1. The *HX* relay now operates via ***P*1**, arcs 2 and 1 of the allotter, to battery at the 150 Ω resistor *YA*. As before, the *P* relay is released at ***HX*1** and the *HX* relay in turn is released at *P*1. All relays of the control relay set are now normal and the allotter is standing on its 1st contacts.

On receipt of a further start signal, the allotter proceeds to test all linefinders, both directly-connected and indirectly-connected. Relay *S* operates to the start signal as described previously, and *HX* operates via ***S*5** to the battery at *YA*. The ***HX*1** contact cannot operate relay *TR* on this occasion because the latter relay is short-circuited by the earth on the 1st contact of allotter arc No. 8. The operation of relay *S* places relay *SF* in parallel with the *YA* resistor, and this relay now operates in series with relay *HX*. ***SF*1** provides a hold circuit for *SF* and at the same time applies a short circuit to relay *HX*. The restoration of *HX*1 completes the allotter drive circuit, and the latter searches for a free linefinder.

The operation of ***SF*2** provides for the testing of all linefinders and not only the directly-connected ones as described previously. When a disengaged linefinder (presumed here to be an indirectly-connected one) is found, relay *HX* operates to the battery at *GP*1 via the *N*2 springs of the linefinder. The drive is cut at ***HX*1**, and this contact also provides a circuit for relay *TR* which operates. ***TR*2** applies earth to the 8th arc of the allotter switch to complete the circuit of the selector hunter driving magnet. The latter now hunts under the control of the *Fdm* springs until a free selector is encountered. At this stage the *FT* relay operates to the free battery condition on the *P*-wire, and at ***FT*1** disconnects the selector hunter drive circuit. The *FR* relay now operates to pre-operate the 1st selector *A* relay as shown in Fig. 475 and the circuit operation proceeds as before.

Group Control. The right-hand portion of Fig. 476 shows the group control circuit. Relay *GP* in this circuit is short-circuited by earth if there is one or more group selectors available in the common pool which is accessible from the selector hunters. Similarly, relay *GPA* is normally short-circuited by earth applied via the *N*3 springs of any disengaged directly-connected linefinders in the unit. A further short circuit is applied under the control of *GP*2 from the *N*3 contacts of all free indirectly-connected linefinders. Thus, relay *GP* operates whenever all

indirectly-connected group selectors are engaged. Similarly, relay *GPA* operates if all the directly-connected finders of the unit are engaged and all the indirectly-connected finders, or indirectly connected group selectors, are also engaged.

Hence, the opening of contact ***GP*1** indicates that a call cannot be completed via indirectly-connected linefinders due to the unavailability of group selectors. The operation of ***GP*1** disconnects the battery potential from all the contacts of allotter arc No. 2 which are associated with the 25th contacts of allotter arcs 1 and 2, ***GPA*1**, *LC*1, to the battery at resistor *YB*. Relay *LC* is also connected in parallel with *YB* so that both *HX* and *LC* operate when the wipers step to the 25th position. ***HX*1** cuts the allotter drive circuit, whilst ***LC*1** disconnects the *YB* resistor, and the reduced current now allows relay *HX* to release. (***LC*4** disconnects the allotter drive circuit in readiness for the release of *HX*1.) The allotter now remains on contact 25 until the congestion condition is removed, i.e. until *GPA*1 disconnects the

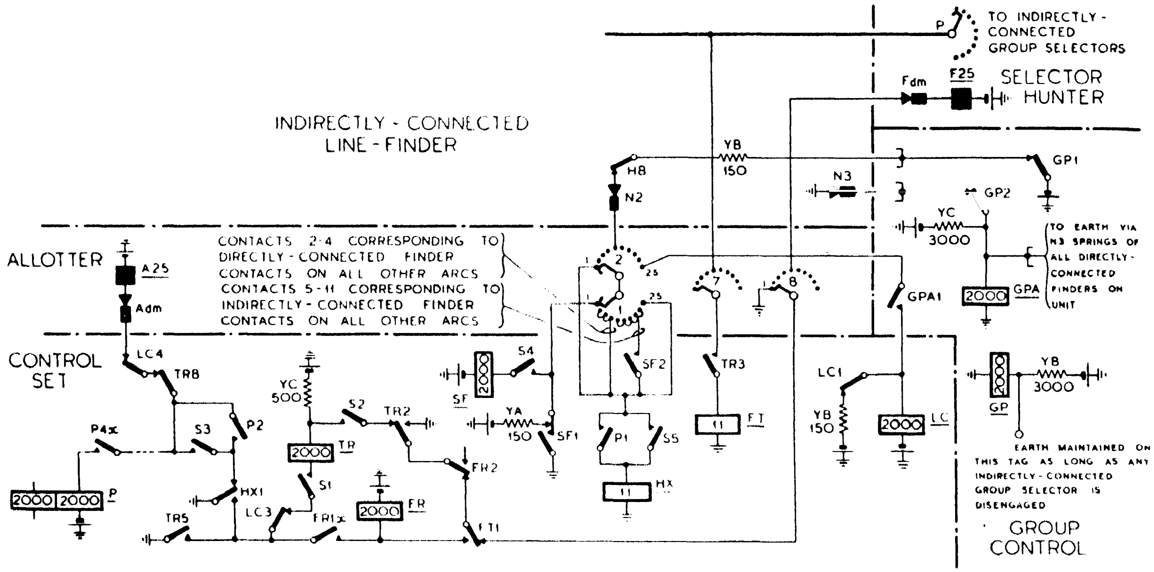


FIG. 476. METHOD OF BRINGING INTO USE INDIRECTLY-CONNECTED LINEFINDERS

indirectly-connected linefinders. It is now impossible for the allotter to switch to any indirectly-connected linefinder until the congestion condition ceases, i.e. until *GP*1 restores.

The closure of contact ***GPA*1** indicates that there is complete congestion on both the directly-connected and the indirectly-connected finder groups. Contact ***GPA*3** (see Fig. 474) applies a 1 sec clock pulse to the group-occupancy time meter for so long as complete congestion remains.

It has been seen that relay *P* is held whilst the allotter steps on after establishing a call. The allotter drive continues until a free linefinder is encountered or until the allotter wipers reach the 25th position. (If all linefinders are engaged, there is no circuit for relay *HX* on the intermediate contacts due to the operation of the ***N*2** contacts in the linefinder circuit.) If full congestion conditions exist, when the allotter reaches the 25th position, relay *HX* (Fig. 476) operates via ***P*1**, holding circuit for relay *LC*. The restoration of *LC*4 permits the allotter to step to the first contacts of the bank. *HX* operates to the battery at *YA*, and at ***HX*1** disconnects the circuit of relay *P*. *P*1 in turn breaks the circuit of *HX* and all relays are now normal pending the receipt of the next start signal.

The arrival of a start signal operates relay *S* as already described, and ***S*5** completes a circuit for relay *HX* to the battery at *YA*. ***S*4** also completes a circuit for *SF* to the same battery, and ***SF*1** in operating provides a holding circuit for *SF*, and a short circuit across relay *HX*. The release of *HX*1 now completes the allotter driving magnet circuit (via ***S*3**), and search for a free linefinder proceeds in the normal way. The directly-connected linefinders appear first on the bank, and if one of these is free the *HX* relay switches to it. If, however, all the directly-connected linefinders are engaged, a circuit is provided via ***SF*2** for the

testing of the indirectly-connected linefinders, and the search continues until a free linefinder is reached.

In the above description it has been assumed that relay *P* holds during the momentary operation of ***HX*1** when the latter is energized to resistor *YB* on the 25th allotter bank contacts. If *P* releases under these conditions, *P*1 disconnects the holding circuit for *LC* so that the allotter stays on the 25th bank contacts even when the congestion condition is removed by the release of *GPA*1. The movement of the wipers to the first set of bank contacts is now dependent upon the next start signal which completes the allotter drive circuit at ***S*3**. The circuit operation from this point is as described.

Allotter Faults. Fig. 477 shows arcs 1 and 2 of the allotter switch in somewhat greater detail. Each unit of 100 calling equipments and 10 linefinders has one control R.S. and one allotter. In order to safeguard against breakdown should the control or allotter become faulty, arrangements are made for the use of the allotter and control set of an adjacent A unit. Thus, if any control set or allotter should develop a fault, its duties are taken over by the companion circuits in the partner unit. The latter then deals with the calls from a maximum of 200 subscribers.

Relay *TB* in each control set is normally held in the operated condition by the current from contact ***TB*6** through the 5000 Ω coil. Let it be assumed that control set No. 2 of Fig. 477 develops a fault and that there is no congestion at this time. If a start signal is received in control set No. 2, relay *TA* operates via ***S*6** to the first application of the *S* pulse and locks at contact ***TA*1**. Normally the linefinding operation should be completed within a period of 6 sec, but if, due to a fault, the control set does not complete its function within this period, relay *TA* will still be held by contact ***P*5** or ***S*7**. If congestion conditions occur during this period, then *TA* is forcibly released by the operation of ***LC*2**.

The *Z* pulse follows 6 sec after the *S* pulse, and if *TA* is operated at this time a circuit is provided (at ***TA*2**) for the 1000 Ω coil of the *TB* relay. This relay is differentially wound and the current due to the *Z* pulse opposes the magnetization of the normal holding circuit. *TB* therefore releases and at *TB*2 diverts the start signal to the partner control set.

In the partner control circuit the diverted start signal operates relay *C* via ***TB*3** (normally operated)

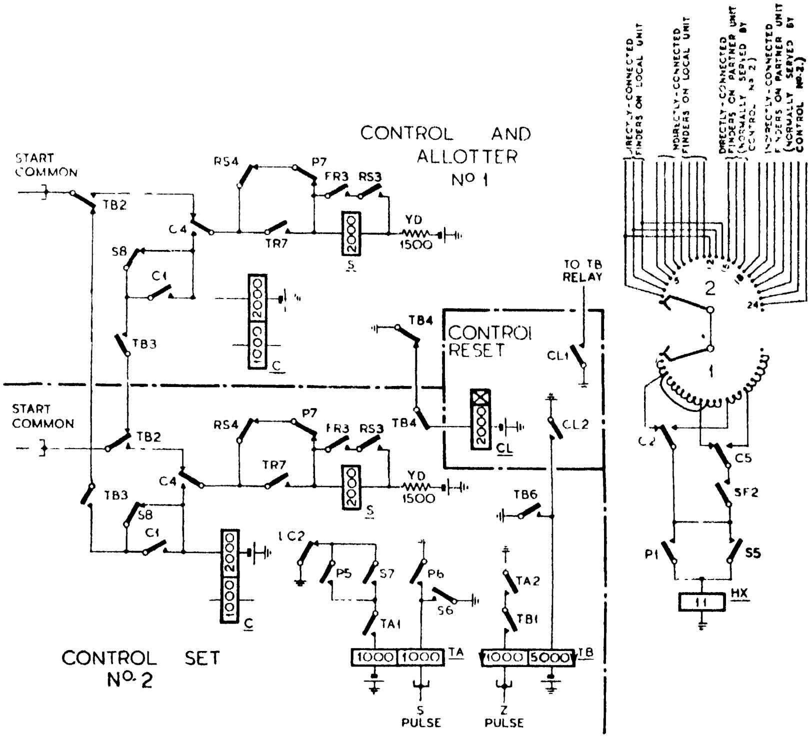


Fig. 477. Interworking of Partner Control Sets Under Fault Conditions

and *S*8. The *C* relay locks to the start signal via contact ***C*1**, whilst ***C*2** and ***C*5** switch over the allotter arc No. 1 connexions so that relay *HX* of the No. 1 control circuit will test the linefinders on the partner unit. It may so happen that at this time the No. 1 control circuit is already dealing with a call originating from its own unit. In such circumstances contact ***S*8** guards against interference from a faulty partner unit.

If the No. 1 control set is disengaged, the operation of relay *C* extends the diverted start signal (at ***C*4**) to operate relay *S*. Contacts of *S* complete the allotter drive as on a normal call. This drive continues until the allotter wipers reach their

15th contacts. Contacts 15 to 24 are trunked to the linefinders in the partner unit, and the search now proceeds for a free linefinder in the unit from which the start signal originates. In due course a free linefinder is seized, and relay *HX* operates to cut the allotter drive circuit. Control set No. 1 now proceeds to control the movements of the linefinder in the manner already described. Control set No. 1 will continue to deal with calls, both from its own unit and from the partner unit, until the partner unit control is restored to service.

Should a fault now develop in control set No. 1, relay *CL* (control re-set circuit) operates via the *TB*4 contacts of both control sets. Contacts ***CL*1** and ***CL*2** re-energize the *TB* relays in both units to restore normal conditions. A high percentage of the control set and allotter faults are of an intermittent or temporary nature, and the restoring feature will in most cases re-establish the service to the subscribers.

We have seen that there is normally only one control set on each unit, safeguards being provided against the failure of this unit by the partnership scheme described above. Where there is an odd number of units in an exchange, the last unit, which has no partner, is equipped with two control and allotter sets. In such cases it is usual to connect 50 calling equipments to each of the control sets. The circuit arrangements are such that, should either control fail, its start signals are diverted to the remaining control set (see Fig. 474). In this case, however, the *C* relays are not used, since all the finders concerned are on the same unit and are normally available to both allotters.

Discriminating Signals. As in the U.A.X.s 12 and 13, the No. 14 type equipment is designed on the basis of a common switching train with a system of discriminating signals to give various alternative facilities. Discrimination is required in respect of:

(1) A signal between the 1st group selector and the final selector to indicate whether a call is to be directed to the 2000's group or the 3000's group depending upon the initial digit (2 or 3).

(2) A signal from a coin-box line circuit through the group selectors to the outgoing junction relay group to indicate that the caller is to be barred access to multi-fee routes.

(3) A means of signalling to the outgoing parent exchange junction terminations to indicate:

(*a*) if the call is to be directed to the automatic equipment at the parent centre;

(*b*) to bar coin-box subscribers access through the automatic equipment at the parent centre to multi-fee routes;

(*c*) a distinctive signal on calls to the parent operator ("0" level calls) from ordinary subscribers;

(*d*) an alternative signal on calls to the parent operator from coin-box subscribers.

(4) A signal to open up trunk offering facilities on calls from the parent exchange or to repeat the trunk offering signal to a dependent exchange.

(5) A signal to withdraw route restrictions on tandem dialled calls.

The discriminating signals used for trunk offering and for the unbarring of outgoing routes to incoming traffic are identical to those used in the U.A.X. 13. There is therefore no need for further explanation of the basic principles. (It will be recalled that the trunk offering signal is a low resistance + battery on the *M*-wire, which is transmitted through the group selector to operate a discriminating relay in the final selector. Similarly, the route "unbarring" signal is a + battery through a high resistance transmitted in the same way over the meter wire to the outgoing junction relay group.)

Coin-box circuits are distinguished by the application of − battery on a special *CB*-wire which is extended to the group selector. Discriminating signals are passed forward from the 1st group selector to the final selector or to the outgoing junction relay set. These signals take the form of light and heavy currents from a − battery and are applied as described in the following paragraphs.

Final Selector Group Switching. It has already been explained that the U.A.X. 14 employs a "pairing" principle on the trunks between the 1st group selectors and the final selectors. The 1st group selector is arranged to absorb the first digit and to determine from this digit whether the final selector wipers are to be switched to the 2000's or the 3000's group of subscribers. Fig. 478 shows how this discrimination is effected and the method of signalling to the final selector.

If a caller dials a local subscriber's number in the 2000's series, the 1st group selector is stepped to the 2nd level, and the circuit is arranged so that the wipers restore to normal during the inter-digital pause. The second digit again steps the group selector vertically, and the wipers now automatically rotate over the selected level to seize a free final selector in the required group. The two final digits position the wipers of the final selector, and the caller is extended via contacts *WS*2 and *WS*3 to the required number. There are no discriminating signals on such a call, and it is unnecessary to operate any switching relays in the final selector.

If the call is to a subscriber in the 3000's series of numbers, the group selector is stepped vertically in response to the first digit as before. During the interdigital pause, relay *C* releases in accordance with normal practice, and at *C7* extends earth from the vertical marking wiper to operate relay *RN*. *RN* now locks via ***RN3*** to the temporary holding earth provided by the *B* relay. The wiper carriage is now released as before and is again stepped vertically in response to the second digit dialled by the subscriber. At the end of this digit, rotary search takes place over the selected level, and in due course relay *H* operates when the group selector switches to a free final selector. ***H3*** now extends — battery via the is stepped to the 3rd level in response to the *second* digit dialled by the subscriber.

Discriminating Signals on Calls over Parent Route. It is the usual practice to provide a single group of junctions to the parent exchange to serve both "9" and "0" level calls from either ordinary or from coin-box subscribers. All parent exchange calls are routed from level 9 of the group selectors (irrespective of whether or not the subscriber dials "9" or "0"). This means that discriminating signals must be passed forward from the group selector to the outgoing junction relay group to determine whether the call is to be routed to the parent manual board or to the automatic equipment at the parent centre. A further set of signals

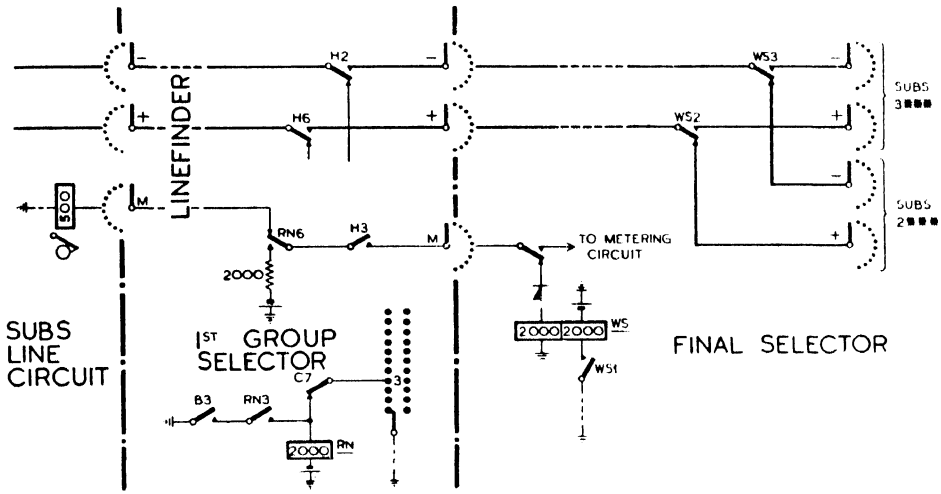


FIG. 478. DISCRIMINATING SIGNAL FOR FINAL SELECTOR GROUP SWITCHING

2000 Ω resistor and ***RN6*** to the forward meter wire and thence to operate relay *WS* in the final selector. *WS* locks at ***WS1*** for the duration of the call, and at ***WS2*** and ***WS3*** prepares for the switching of the call to the sections of the bank which serve the 3000's group of subscribers. In accordance with standard practice, the operation of the switching relay (*H*) removes the *A* relay from the speaking pair, and the *A* contacts in turn disconnect the circuit for relay *B*. After a period of some 300 msec, *B3* releases *RN*, and *RN6* removes the discriminating signal from the *M*-wire and restores the latter in readiness for the transmission of the metering signal from the final selector when the called subscriber replies.

The exact circuit arrangements of the group selector are considered in more detail in later paragraphs. In the meantime it will be noted that the circuit must provide facilities for preventing the operation of relay *RN* if the selector is required to distinguish between calls from ordinary subscribers and those from coin-box subscribers. Fig. 479 shows the circuit arrangements in the group selector which provide the necessary discriminating signals and also the relays in the outgoing junction termination which respond to these signals.

Several alternative types of call are considered:

"9" *Level Call from Ordinary Subscriber.* The group selector is stepped vertically in response to the first digit from the calling subscriber's dial. During the transmission of the 9th impulse to the vertical magnet, the normal post springs (***NP9***) operate and connect earth to one side of the 1000 Ω coil of relay *PA*. This coil is, however, short-circuited during the period when the *A1* contact is released, but, at the end of the 9th impulse, the re-operation of ***A1*** removes the short circuit from relay *PA* and allows it to operate in series with the vertical magnet. (The magnet does

not, of course, operate due to the high resistance of the circuit.) During the interdigital pause, the wipers are stepped over the 9th level and, when a free junction to the parent exchange is seized, relay *H* operates to switch the call through to the outgoing junction relay set. On calls of this type, relays *CB* and *WS* (group selector) are normal, so that the meter wire is extended through the group selector from the moment of switching, i.e. although relay *PA* is operated the contacts of this relay are ineffective and no discriminating signal is cribed for an ordinary call. In this case, however, — battery via a 500 Ω resistor is extended over the *CB*-wire to the group selector so that, when a free junction to the parent centre is seized, relay *H* operates and at ***H7*** completes a circuit for the operation of the *CB* relay. At the moment of switching, the closure of the ***H3*** contact completes the *M*-wire circuit (as on a call from an ordinary subscriber). Within a few milliseconds, however, contact ***CB2*** changes over to extend the forward *M*-wire to the ***PA2*** contact, but the latter

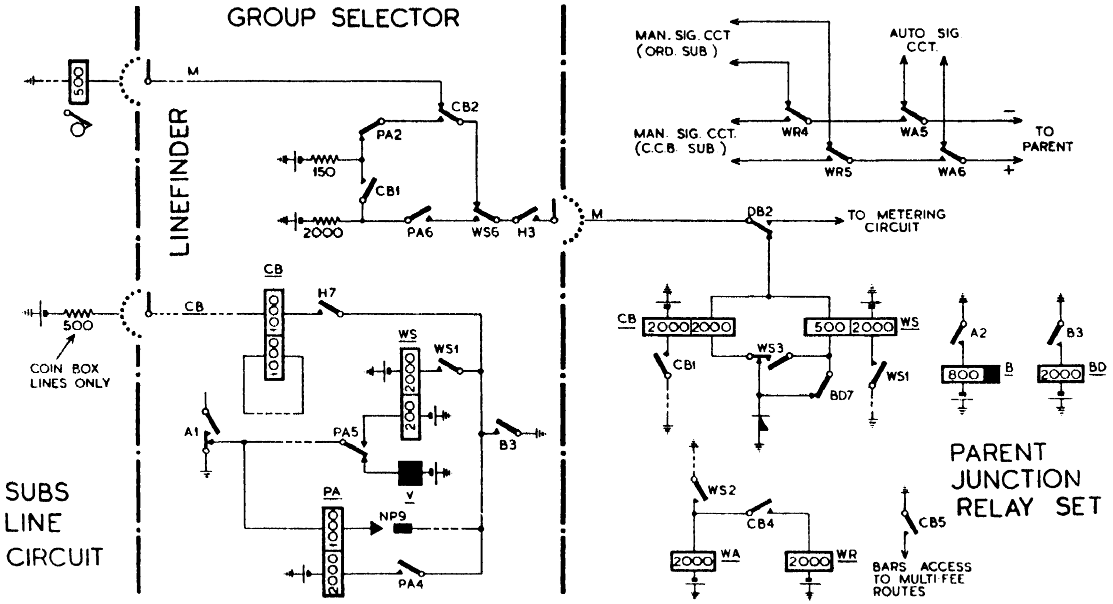


FIG. 479. DISCRIMINATING SIGNALS TO PROVIDE APPROPRIATE SIGNALLING CONDITIONS ON PARENT ROUTE

(Combined "9" and "0" level traffic)

passed forward from the group selector to the outgoing junction relay set.

"9" *Level Calls from Coin-box Subscribers.* If the parent centre is outside the unit-fee radius of the U.A.X. 14, then coin-box callers are barred all access to the parent automatic equipment. (This is obtained by certain connexions to the vertical marking bank of the group selector as described later.) If, on the other hand, the parent centre is within 5 miles of the U.A.X., it is possible to give access from coin-box subscribers, but means must be provided of preventing the coin-box user from tandem dialling through the parent automatic equipment to obtain other exchanges beyond unit-fee radius. When a coin-box subscriber dials "9," the wiper carriage of the group selector is stepped to the 9th level, and relay *PA* operates at the end of the 9th impulse as already described for an ordinary call.

is held operated at this stage under the control of the group selector *B* relay.

The operation of the switching relay (*H*) extends the calling subscriber's loop to the outgoing junction relay set and at the same time disconnects the *A* relay of the group selector in accordance with normal practice. The extended loop operates the line relay in the outgoing junction relay set, and this relay in turn operates the guard relay (*B*) of the outgoing junction equipment. ***B3*** operates *BD* and contact ***BD7*** disconnects the coil of relay *WS*. These operations all occur within, say, 20 msec of the switching of relay *H* in the group selector. The disconnexion of relay *A* in the group selector breaks the circuit of the *B* relay in that circuit, and some 300 msec later the release of the *B3* contact breaks the holding circuits of relays *PA* and *CB*. *PA* is quick-to-release,

but *CB* is slugged by a short circuit across its second winding. There is therefore a time interval of 100 msec or so between the release of *PA* and the release of *CB*. During this time − battery via a 150 Ω resistor is extended via *PA*2, ***CB*2**, *WS*6, and ***H*3** to the meter wire of the outgoing junction relay group. This battery condition operates relay *CB* in the latter, and *CB* in turn locks for the duration of the call at local contacts. Contact ***CB*5** signals to the auxiliary equipment associated with the junction relay group to indicate that all multi-fee dialling codes are to be barred. Particular note should be taken of the delay in the transmission of the coin-box discriminating signal which is necessary to prevent the operation of relay *WS* in the outgoing junction equipment. Premature connexion of the coin-box signal would result in the call being routed to the parent manual board instead of to the automatic equipment at the parent centre.

"0" *Level Call from Ordinary Subscriber.* If an ordinary subscriber dials "0," the wiper carriage is stepped to the 9th level in response to the first 9 impulses of the train. Relay *PA* operates as previously described when contact ***A*1** re-operates at the end of the 9th impulse. ***PA*5** now changes over the impulsing circuit from the vertical magnet to the 200 Ω coil of the *WS* relay. (It will be noted that this changeover occurs when there is no current flowing.) *A*1 releases at the commencement of the 10th impulse and earth is extended via ***PA*5** to operate relay *WS*. Relays *WS* and *PA* are now held via their own contacts to the earth at ***B*3**. Rotary search commences when the group selector *C* relay releases at the end of the impulse train, and in due course relay *H* operates when a free outgoing junction is seized. Negative battery via the 2000 Ω resistor is extended via ***PA*6**, ***WS*6**, and ***H*3** to the meter wire of the outgoing junction relay group. (Note that this discriminating signal is applied from the moment of switching.) The battery on the *M*-wire operates relay *WS*, but the current is insufficient to operate relay *CB*. ***WS*1** provides a holding circuit for *WS* for the duration of the call, whilst ***WS*3** places the *CB* relay circuit under the control of contact *BD*7. The extension of the loop to the outgoing relay set operates relays *A*, *B*, and *BD* within a period of some 20 msec, and the opening of contact ***BD*7** prevents any possibility of the operation of relay *CB* due to fortuitous conditions on the *M*-wire. Contact ***B*3** in the group selector releases after a period of some 300 msec from switching, and in turn releases relays *PA* and *WS*. *WS*6 now removes the discriminating battery and restores the *M*-wire.

The operation of relay *WS* in the outgoing junction relay set completes a circuit for relay *WA*. Contacts ***WA*5** and ***WA*6** disconnect the normal loop calling conditions on the junction and apply the correct signals to light the "ordinary subscriber" calling lamp at the parent manual board. (It will be recalled that the initial seizure signal for a call of this type is a − battery on the + wire.)

"0" *Level Call from Coin-box Subscriber.* If a coin-box subscriber dials "0," relay *PA* operates at the end of the 9th impulse, and relay *WS* operates at the commencement of the 10th impulse as described above. The wipers search over the 9th level and, when relay *H* switches to a free parent junction, relay *CB* operates due to the presence of the 500 Ω battery extended from the coin-box line circuit. The closure of the ***H*3** contact extends the 2000 Ω battery forward on the *M*-wire. Within a few milliseconds, the closure of contact ***CB*1** shunts the 2000 Ω resistor by 150 Ω. Relays *WS* and *CB* in the outgoing junction relay group both operate to the low resistance battery on the *M*-wire before contact *BD*7 disconnects the circuit. ***WS*2** operates relay *WA*, whilst ***CB*4** completes a circuit for relay *WR*. Contacts ***WA*5**, ***WA*6**, and ***WR*4**, ***WR*5** now transmit the correct signalling conditions to the junction to light the coin-box calling lamp at the parent manual board.

Outgoing Calls to Non-parent Exchanges are routed from levels 4 to 8 of the 1st group selectors. On such calls there is no circuit for the operation of relay *PA* or relay *WS*, but if the call emanates from a coin-box subscriber relay *CB* operates when the group selector switches the caller to a free outgoing junction or to the next switching stage. There are therefore no discriminating signals on calls from an ordinary subscriber, but − battery via 150 Ω is extended via *PA*2, ***CB*2**, *WS*6, and ***H*3** if the call originates from a coin-box line. This signal is transmitted within a few milliseconds of switching (i.e. when ***CB*2** operates) and is withdrawn some 300 msec later when *CB* is released by the restoration of contact *B*3. The *M*-wire is now restored at *CB*2 in readiness for the transmission of meter pulses when the called party replies.

On non-parent routes the outgoing junction relay set contains a *CB* relay which is designed to respond to the 150 Ω battery extended over the *M*-wire on coin-box calls. Contacts of this relay signal to the multi-metering equipment that all multi-fee codes are to be barred. There is, of course, no *WS* relay on non-parent routes—loop signalling being employed on calls of all types.

1st Group Selector. Fig. 480 shows the complete circuit of a 1st group selector at a U.A.X. 14. The circuit provides for:

(*a*) The transmission of dial tone to the caller on seizure.

(*b*) The absorption of the initial digit on local calls.

(*c*) Vertical stepping in response to the second digit on local calls, and rotary search over the being passed to the outgoing parent junction relay set to distinguish between "9" level calls, "0" level calls, and calls from coin-box subscribers.

(*i*) N.U. tone is transmitted to the caller if the level dialled is spare. N.U. tone is also transmitted to coin-box subscribers if the level dialled is barred.

(*j*) Busy tone and flash are returned to the caller if all outlets on a selected level are engaged.

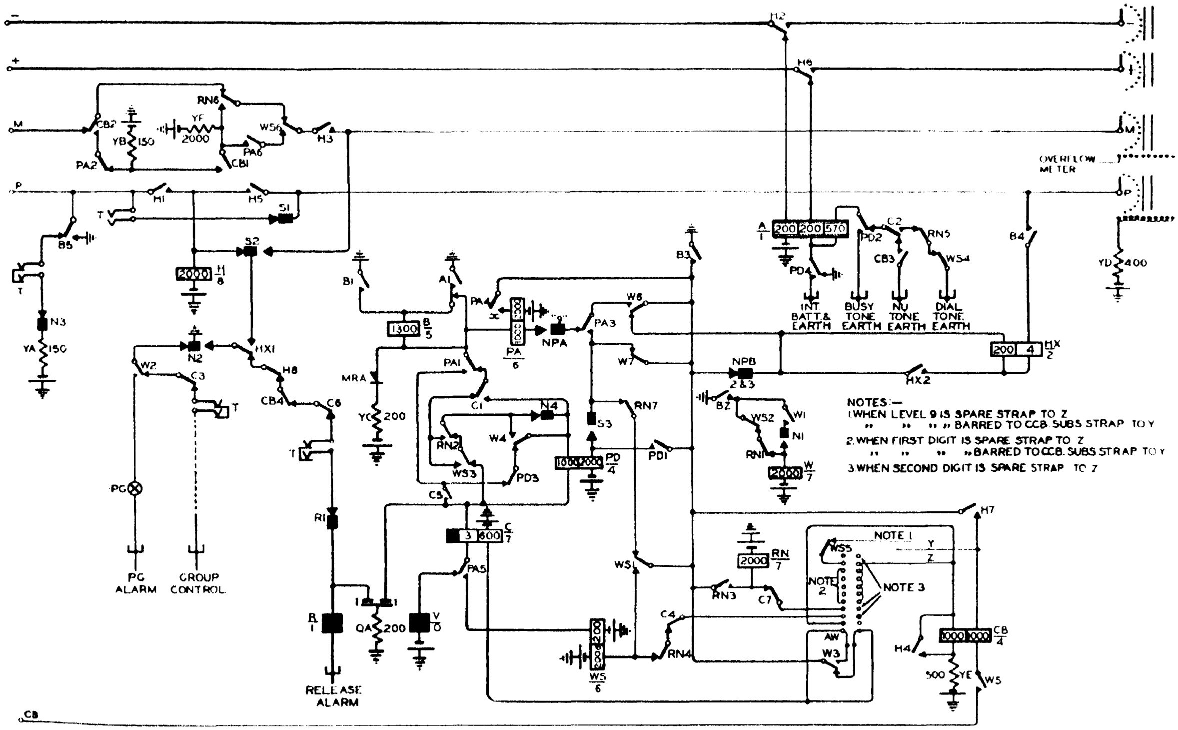


FIG. 480. 1ST GROUP SELECTOR CIRCUIT

selected level to seize a final selector in the required group.

(*d*) The transmission of a discriminating signal to the final selector if the call is to be routed to a subscriber in the 3000's series.

(*e*) The transmission of busy tone to the caller if the second digit (on local calls) arrives before the selector has fully restored from the initial digit.

(*f*) The selector steps vertically in response to an outgoing junction dialling code, and searches over the selected level to seize a junction in the required group.

(*g*) On calls to non-parent exchanges, a coin-box discriminating signal is transmitted to the outgoing junction equipment to provide route barring on all multi-fee codes.

(*h*) "9" and "0" level calls are routed from level 9 of the selector, suitable discriminating signals

(*k*) The circuit provides the normal facilities for P.G. alarms, release alarms, and the operation of an overflow meter if all outlets on the selected level are engaged.

The circuit follows the usual practice of 2000 type design, an interesting feature being the adoption of battery testing both on the incoming and on the outgoing sides of the selector.

Digit Absorption and Group Discrimination. We have seen that all subscribers' numbers on a U.A.X. 14 commence with digits 2 or 3, and that the initial digit is absorbed by the 1st group selector to provide a discriminating signal to the final selector. Fig. 481 shows the circuit elements of the 1st group selector concerned. The circuit must make provision for:

(*a*) The establishment of the release circuit if the wiper carriage is stepped to either the 2nd or

the 3rd level. Since the selectors are of the 2000 type, the wipers pass over the bank contacts of the level during the release action, and hence the normal testing circuit must be disconnected during rotary release.

(*b*) The marking conditions on the 2nd and 3rd levels must be removed before the wiper carriage is stepped vertically for the second digit in order to prevent a repetition of the release action.

(*c*) If the initial digit is 3, a discriminating signal must be passed forward to the final selector to provide wiper switching to the 3000's group.

When the 1st group selector is taken into use, the energization of the line relay (*A*) operates relay *B*, and *B* in turn operates relays *C* and *W*. The subsequent operation is as follows:

Initial Digit 2. If the subscriber requires a number in the 2000's series, the wiper carriage is stepped to the 2nd level as in any other 1st group selector. At the end of the impulse train, relay *C* releases, and at *C*4 extends the earth from ***B*3** via ***W*3**, the vertical marking bank, *C*4, and *RN*4 to operate relay *WS*. *WS* locks at ***WS*1** to the selector common earth. The release of relay *C* also completes the rotary drive circuit at *C*6, and the wipers are rotated over the 2nd level. The testing relay circuit is, however, broken at ***W*6** and at the normal post springs (***NP***), so that *HX* cannot operate to any free condition on the *P* bank. The wipers therefore drive to the 12th rotary position, and the selector carriage restores to the normal level. At this point the holding circuit for relay *W* is broken (at *N*1), whilst *N*2 disconnects the rotary drive.

The subscriber now dials the second digit, but the vertical marking bank circuit is disconnected at *W*3. When relay *C* releases at the end of the impulse train, the wipers cut into the selected level and search continues under self-interrupted rotary drive. During this second rotary movement, earth is connected to the testing relay (*HX*) via *W*6 which is now normal. *HX* therefore operates to a battery condition on the *P*-wire, and in turn energizes the switching relay *H*. Contacts of relay *H* switch through the speaking pair and after the usual period of lag relay *B* restores and breaks the holding circuit of relay *WS*. No discrimination signals are passed forward to the final selector, the meter wire being extended through the group selector from the moment of switching.

Initial Digit 3. If the first digit dialled by the subscriber is 3, the wiper carriage is moved to the 3rd level and relay *RN* operates when contact *C*7 restores during the interdigital pause. *RN* holds (at ***RN*3**) to the selector common earth. The rotary drive circuit is completed at *C*6, but the testing relay is disconnected during rotary drive at ***W*6** and ***NP*** as before. When the selector reaches normal, the opening of the *N*1 contacts releases relay *W*. The subscriber now dials the second digit, and the wipers are stepped to the level corresponding with the 100's number of the required subscriber. During vertical stepping, the vertical marking wiper circuit is broken at *W*3 so that relay *WS* does not operate if the digit 2 is dialled. During the interdigital pause the wipers rotate over the selected level in search of a final

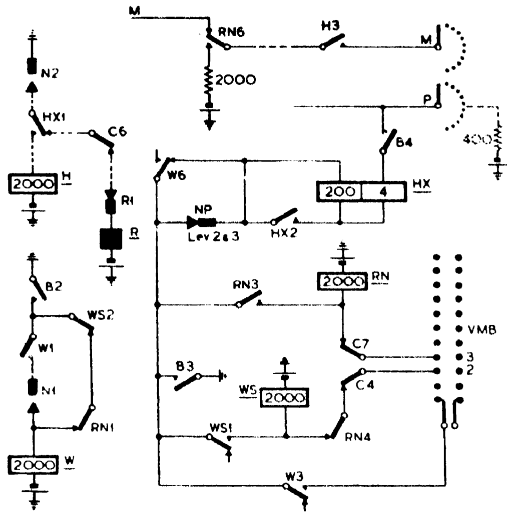


FIG. 481. METHOD OF ABSORBING INITIAL DIGIT ON LOCAL CALLS AND PROVISION OF FINAL SELECTOR GROUP SWITCHING SIGNAL

selector, and when a free condition is encountered on the *P*-wire relay *HX* operates. *HX* now operates relay *H*, and the contacts of the *H* relay in turn switch the call through to the final selector. At the moment of switching ***H*3** extends − battery via the 2000 Ω resistor and contact ***RN*6** to the *M*-wire of the final selector. This discriminating signal operates a wiper switching relay in the latter to direct the call to the bank which accommodates subscribers' numbers in the 3000's series. Relay *H* (group selector) disconnects relay *A* from the loop, and *A* in turn disconnects the holding circuit of *B*. After a period of some 300 msec, *B*3 releases relay *RN*, and the discriminating signal is withdrawn by the restoration of *RN*6. The *M*-wire is now switched through in readiness to receive the metering condition at a later stage.

Premature Dialling of 2nd Digit on Local Calls. It has been seen that when the initial digit for a

local call has been dialled, the following operations must take place during the interdigit pause:

(*a*) The *C* relay must release, and the *WS* relay or *RN* relay must operate.

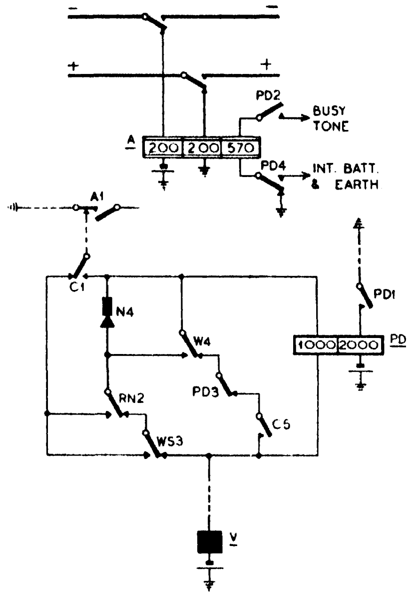


FIG. 482. CIRCUIT ARRANGEMENTS FOR THE RETURN OF THE ENGAGED SIGNAL IF THE SECOND DIGIT IS RECEIVED BEFORE THE GROUP SELECTOR CIRCUIT HAS FULLY RESTORED FROM THE ABSORPTION OF THE FIRST DIGIT

(*b*) The wiper carriage must rotate over the complete level to the 12th rotary position.

(*c*) The wipers must restore to the normal level.

(*d*) The wiper carriage must restore horizontally to the start position.

(*e*) The *W* relay must release.

(*f*) The *C* relay must operate.

Under certain conditions, there is some slight risk that the first impulse of the 2nd digit will arrive before the above cycle of operations is complete. Fig. 482 shows the arrangements which are made for this contingency. The impulse train of the initial digit is routed via **C1**, ***W*4**, *RN*2, and *WS*3. In normal circumstances (i.e. when the selector is ready to receive the 2nd digit) an impulsing path for the second impulse train is provided via **C1**, *W*4, *PD*3, and **C5** to the vertical magnet. The operate coil of the premature dialling relay *PD* is short-circuited under these conditions.

Should the 2nd digit arrive before the restoration of the selector is complete, it will find either:

(*a*) Relay *W* still not released and *C* not re-operated. The first impulse will therefore be routed via *C*1, ***RN*2** or ***WS*3**, and ***W*4** to the 1000 Ω coil of relay *PD*.

(*b*) Relay *W* released but *C* still not re-operated, in which case the first impulse will be routed via *C*1, ***RN*2** or ***WS*3**, and the *N*4 springs to the 1000 Ω coil of *PD*.

PD operates under either condition, and ***PD*3** disconnects the impulsing circuit to the vertical magnet for the 2nd digit. Contacts ***PD*2** and ***PD*4** return the engaged signal to the caller until the call is abandoned.

Treatment of Spare and Barred Levels. The 1st group selector provides facilities for returning N.U. tone if:

(*a*) an ordinary subscriber dials a spare level, and

(*b*) a coin-box subscriber dials either a spare level or a level giving access to a multi-fee route.

Fig. 483 shows the method of obtaining these facilities. During the reception of the first digit, relay *W* is operated so that earth is applied to the left-hand vertical marking wiper via ***W*3**. If,

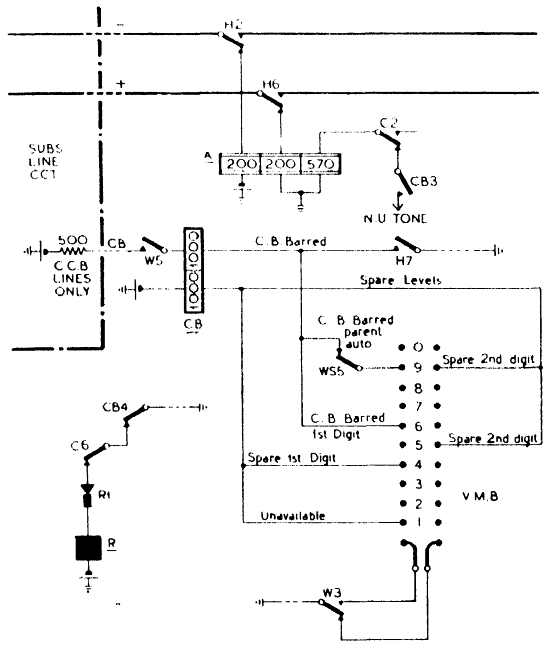


FIG. 483. METHOD OF RETURNING N.U. TONE TO A CALLER IF A SPARE OR BARRED LEVEL IS DIALLED

say, the initial digit 4 is a spare code, the 4th level of the left-hand side of the vertical marking bank is connected to one coil of the *CB* relay so that the latter operates when the wiper carriage reaches the 4th level. When relay *C* releases at the end of the impulse train, *C*2 applies N.U. tone via

CB3 to the 570 Ω winding of *A*. **CB4** prevents the completion of the rotary drive circuit, so that the wipers do not cut into the bank. This condition is maintained until the call is abandoned.

If an initial digit 6 gives access to a route beyond unit-fee range of the U.A.X., level 6 of the left-hand portion of the vertical marking bank inclusion of contact *WS*5 in the connexion to the *CB* relay. Thus, if a coin-box subscriber dials "9," relay *WS* is normal and the route is barred to him by the operation of relay *CB* from the earth at **W3** to the battery in the coin-box line circuit. If, however, the coin-box user dials "0," relay *WS* operates at the commencement of

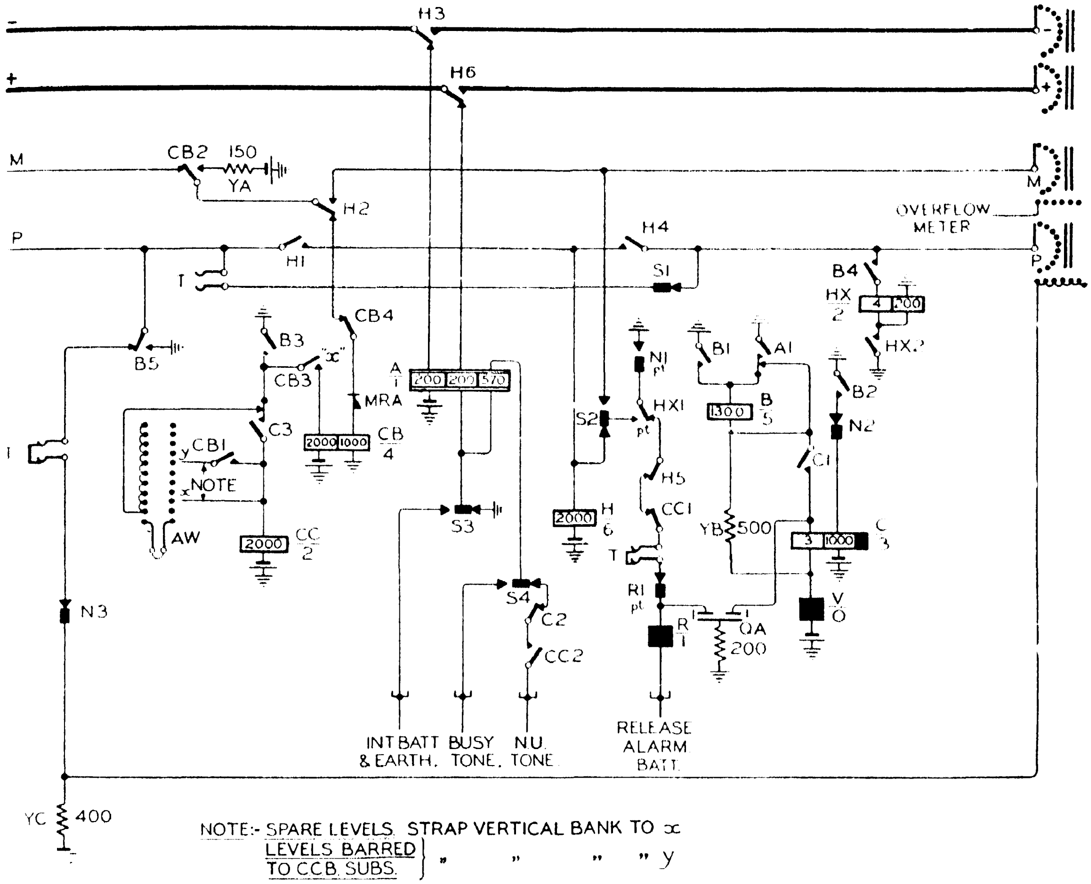


FIG. 484. CIRCUIT OF 2ND GROUP SELECTOR

is connected to the second coil of relay *CB*. When the wipers are stepped to this level, earth is extended from **W3**, but the circuit for *CB* is completed only on coin-box calls where there is an operate circuit to the 500 Ω battery in the coin-box line circuit. *CB* returns N.U. tone to the caller and prevents rotary drive as before.

Where the parent exchange is beyond unit-fee range of the U.A.X., it is necessary to bar access to coin-box subscribers if the digit "9" is dialled, but at the same time a coin-box subscriber must be allowed to seize an outgoing junction to the parent exchange from level 9 of the group selector if he dials an initial digit "0." This is obtained by the the 10th impulse so that *CB* is normal when relay *C* releases at the end of the impulse train.

The right-hand portion of the vertical marking bank is used for returning N.U. tone if the second digit dialled by the subscriber is that of a spare level. The circuit operation is substantially as before, except that *W*3 is normal during the reception of the second digit. If, for example, final selector group 25**–35** is unequipped, N.U. tone is returned to the caller by connecting level 5 of the right-hand portion of the vertical marking bank to the *CB* relay. If the subscriber now dials "5" as the second digit, earth is extended via *W*3 to operate relay *CB* and thence

to return N.U. tone to the caller when relay *C* releases.

2nd Group Selector. Where there is a large number of outgoing junction groups, it may be necessary to trunk a level of the 1st selectors to a group of 2nd selectors in order to provide additional dialling codes. The 2nd group selectors are, like the 1st selectors, of the 100-outlet type, and, in addition to the more usual functions of a group selector, the circuit provides for:

(*a*) The repetition of the coin-box discriminating signal.

(*b*) The transmission of N.U. tone to the caller without the wipers cutting into the bank if the level dialled is spare or if a coin-box subscriber dials a barred level.

Fig. 484 shows the complete circuit arrangements. The repetition of the coin-box discriminating signal is obtained by the operation of relay *CB* over the *M*-wire from the 1st group selector, contact ***CB*2** repeating the 150 Ω battery on the *M*-wire forward to the junction relay group.

The only other point of interest is the method of returning N.U. tone if a spare or barred level is dialled. Relay *CC* is normally dependent upon relay *C* and, in ordinary circumstances, releases when *C*3 restores at the end of the impulse train. Facilities are, however, provided for connecting relay *CC* to any spare levels of the vertical marking bank. Thus, when *C*3 releases at the end of the vertical impulse train, *CC* is held over the circuit provided by the *VMB* wipers. ***CC*2** now returns N.U. tone to the caller, whilst ***CC*1** prevents rotary drive. If the level is accessible to ordinary subscribers, but is to be barred on calls from coin-box subscribers, relay *CC* is connected to the vertical marking bank via a contact (*CB*1) of the *CB* relay. Thus, relay *CC* is held only on coin-box calls. The circuit arrangements are substantially the same as those in the group selector circuit of a U.A.X. 13 and have been described in connexion with Fig. 454.

Ordinary and 2/10 P.B.X. Final Selector. The most common type of final selector fitted at a U.A.X. 14 is illustrated in Fig. 485. The selector provides for:

(*a*) 100 subscribers' lines in each of the 1000's series (2 and 3). The circuit includes a wiper switching relay (*WS*) which can be operated by a discriminating signal received from the 1st selector

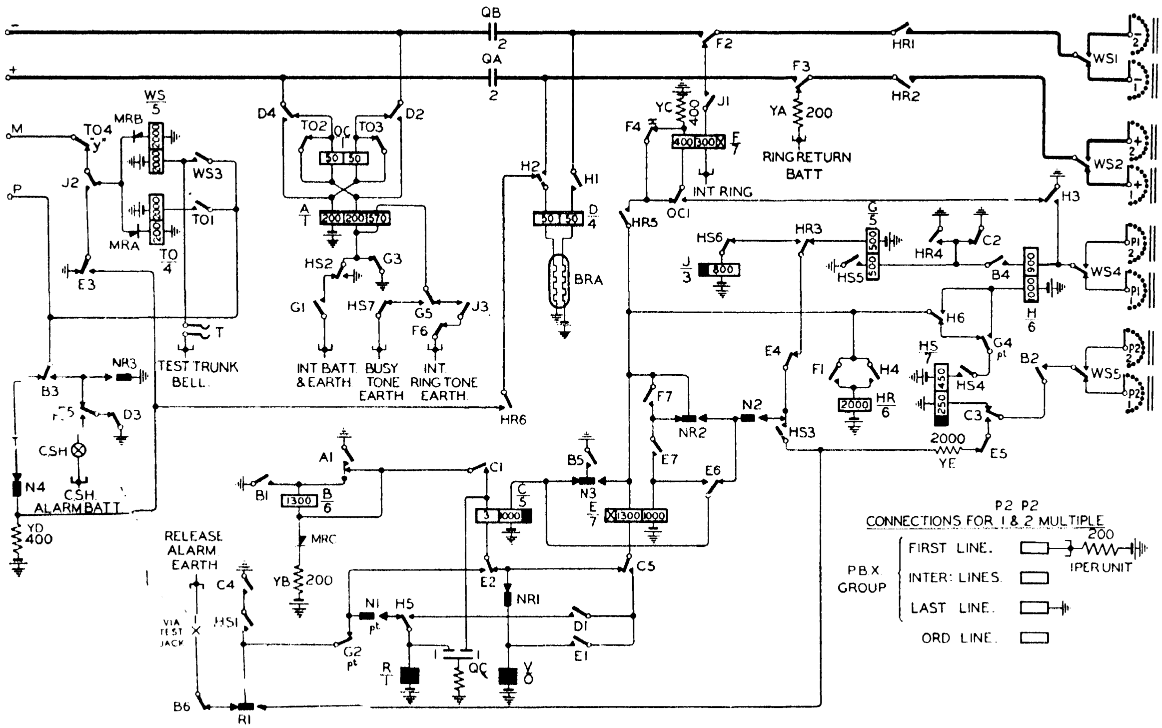


FIG. 485. FINAL SELECTOR CIRCUIT FOR ORDINARY LINES AND FOR P.B.X.S OF UP TO 10 LINES

over the M-wire. The contacts of this relay route the call to the appropriate 100's group.

(*b*) Ordinary (single line) subscribers and for P.B.X. groups of up to 10 lines. The P.B.X. groups can be intermixed with the ordinary subscribers' lines and can be accommodated at any point in the multiple.

(*c*) Trunk offering facilities on calls from the parent exchange. The circuit is arranged so that an earth fault on the junction (which might imitate the trunk offering signal from the parent exchange) releases the final selector immediately on seizure.

(*d*) Metering by – battery over the M-wire.

(*e*) Normal facilities for C.S.H. delayed alarm, and for a test trunk bell to indicate whether the upper or lower bank multiple is in use.

The circuit principles employed in the selector have all been examined earlier in this volume, and it remains only to summarize the main sequence of operations on calls of various types.

Calls to Ordinary Subscribers. If the call is to a subscriber in the 3000's group, relay WS operates to the discriminating battery extended on the M-wire from the 1st selector (Fig. 486). If, on the other hand, the required line is in the 2000's group, no wiper switching signal is received, and the WS relay remains normal to connect the caller to the wipers of the appropriate bank. Seizure of the selector operates relays A, B, and C as usual and, at the end of the 10's digit, C releases and provides an operate circuit for relay E. The latter relay changes over the impulsing circuit to the rotary magnet and re-operates relay C in readiness for the next impulse train. The testing relay (H) is applied to the $P1$ wiper when relay C releases at the end of the units digit. This testing circuit is maintained until such time as relay E releases and allows relay C to re-operate. If the required line is engaged, H does not operate during the testing period, and in due course the release of E completes a circuit for relay G which returns busy tone, etc. If the called line is free, H switches and operates relay HR. The release of E now allows relay J to operate, and contacts of J complete the ringing circuit. When the called subscriber replies, relay F operates and extends the called subscriber's loop to the supervisory relay. Contacts of relay D re-operate relay E, and the latter disconnects the circuit of relay J. Metering battery is now returned on the M-wire during the release lag of relay J. At the termination of the call, the restoration of relays A and B allows all the remaining relays to restore and completes the rotary homing circuit.

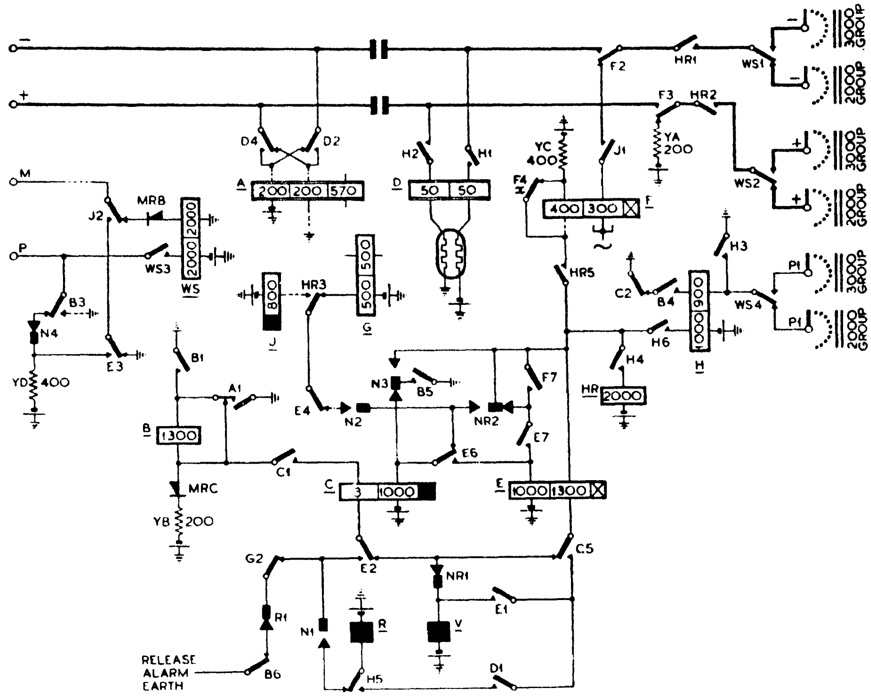


FIG. 486. ELEMENTS OF FINAL SELECTOR CIRCUIT CONCERNED WITH THE SWITCHING OF A CALL TO AN ORDINARY (SINGLE LINE) SUBSCRIBER

Calls to a P.B.X. Subscriber. Fig. 487 shows those portions of the final selector circuit concerned with the automatic hunting feature on P.B.X. lines. The first line of a P.B.X. group is marked by battery potential on the $P2$ bank, whilst the last line of the group has earth connected to the $P2$ bank. Relay HS operates to the marking battery on the $P2$ bank of the first line. If the first line is free, relay H operates and the call proceeds as for an ordinary line. If the first line is engaged, H does not operate during the testing period, and on the re-operation of relay C (after E releases) the rotary drive circuit is completed at **C4**. Relay G interacts with the rotary magnet during rotary drive, and the testing relay

is applied to the $P1$ wiper at each step by contact *HS5*. When a free line is encountered, the holding of relay *G* arrests rotary drive until the switching relay fully operates to disconnect the drive circuit at *H5*. Other contacts of the *H* relay disconnect *HS* and operate *HR*. *HS6* now completes a circuit for relay *J*, and the call proceeds in the normal manner.

If all P.B.X. lines are engaged, relay *G* holds to the earth condition on the last line of the *P2* bank, thereby arresting rotary drive and releasing relay *HS*. Busy tone is now returned to the caller.

Under night service conditions the caller may dial any intermediate number. Relay *HS* does not operate and the call proceeds as if it were made to an ordinary subscriber.

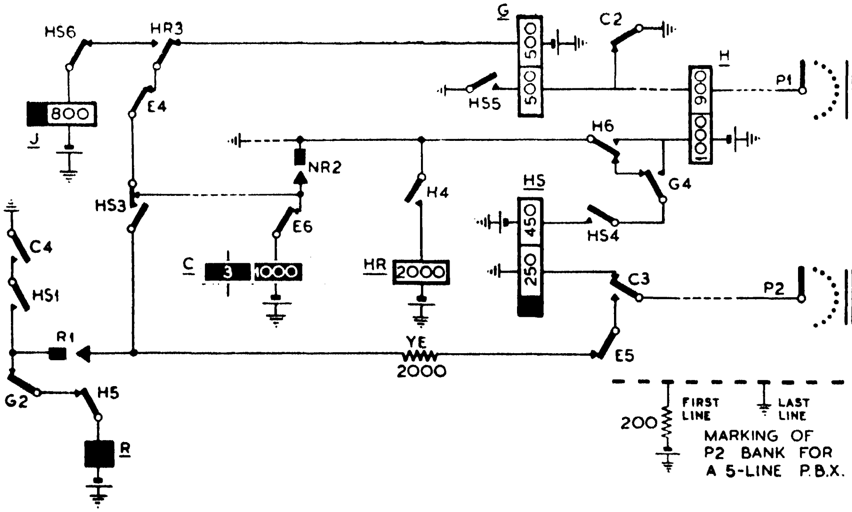


FIG. 487. METHOD OF SEARCHING OVER THE LINES OF A P.B.X. GROUP

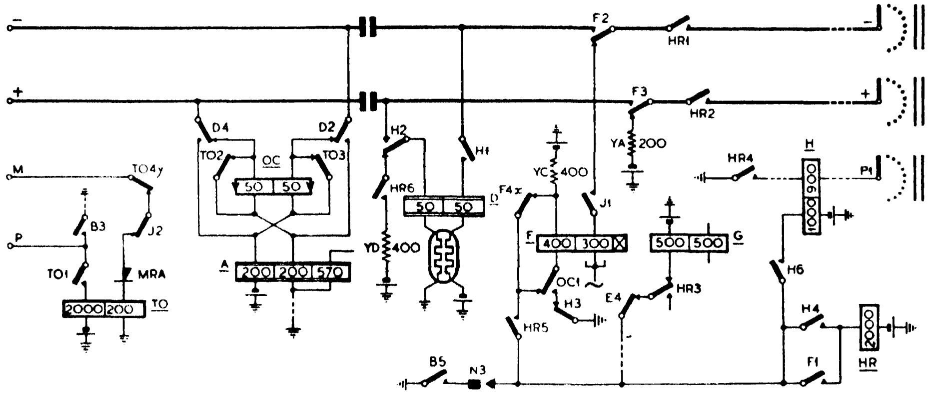


FIG. 488. ELEMENTS OF FINAL SELECTOR CIRCUIT CONCERNED WITH THE OFFERING OF TRUNK CALLS TO AN ENGAGED SUBSCRIBER

Trunk Offering. Fig. 488 shows the portions of the circuit concerned with the offering of trunk calls to an engaged subscriber. Relay *TO* operates to the + battery discriminating signal from the incoming parent junction termination, and switches relay *OC* into circuit. If the required line is engaged, the operator can intercept by operating her ringing key. This applies an earth to the junction pair which, by upsetting the balance of current in the two windings of *OC*, allows the latter to operate. *OC* operates relay *F*, and *F* in turn operates relay *HR*. The contacts of *HR* and *F* now extend the operator to the called subscriber irrespective of the condition on the *P*-wire, whilst the operation of relay *D* (to the

battery via *HR6*) darkens the supervisory signal at the manual exchange. If the called subscriber agrees to accept the trunk call, the local connexion is released and, when the called subscriber's line circuit is normal, relay *H* operates to the battery on the *P*1 bank. This releases relay *D* to light the supervisory lamp at the manual board. The operator now depresses the ringing key a second time, and the consequent operation of the *OC* relay releases relay *F*. Ringing is now applied to the required subscriber's line and, when the called subscriber replies, the call proceeds in the usual manner.

Final Selector with Facilities for Large P.B.X. Group. Occasionally it is necessary to make provision at a U.A.X. 14 for one or two large P.B.X. groups which are beyond the capacity of the final selector just described. A second type of final selector is available for use in such circumstances. This selector contains 3 additional relays together with a vertical marking bank, and, although the number of large P.B.X.s is normally limited to one per final selector group, the circuit arrangements make it possible to accommodate one 20-line P.B.X. in each of the two 100-line multiples. The design of the A unit limits the maximum number of final selectors which can be provided per group, and it is not usually practicable to maintain a satisfactory grade of service if two very large P.B.X.s are included in the same final selector group. Any level (except level 9) can be used for the first level of the large P.B.X., and any other level (including level 9) can be used for the second level of a P.B.X. In all other respects the facilities provided by the larger type of final selector are similar to those of the first type.

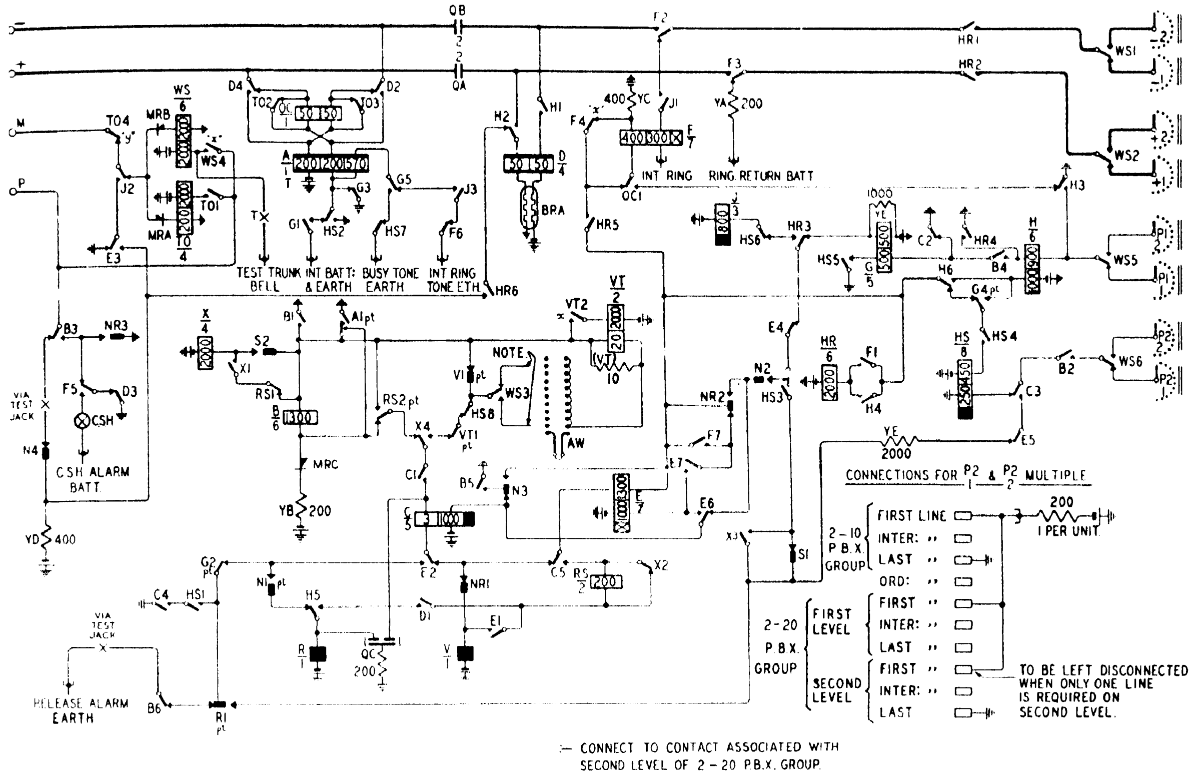


FIG. 489. ALTERNATIVE FINAL SELECTOR CIRCUIT WITH FACILITIES FOR ONE LARGE P.B.X. GROUP OF UP TO 20 LINES

The complete circuit of the final selector is shown in Fig. 489, whilst Fig. 490 shows the elements concerned in the search for a free line in the large P.B.X. group. For purposes of explanation it is assumed that an 18-line P.B.X. occupies levels 6 and 7 of the final selector bank, i.e. the lines are numbered 61–70 and 71–78. The directory number of the P.B.X. is **61. After the dialling of the units digit, the selector tests the first line on the 6th level. If this is engaged, the usual P.B.X. hunting cycle is started. If all other lines on the level are engaged, the

wipers move to the 11th rotary step, and relay *X* operates via the *S2* springs. *X* holds via ***X1***, and the circuit is prepared for the subsequent operation of relay *RS* by the operation of ***X2***. Whilst the rotary armature is attracted, the *G* relay operates via ***X3*** to the earth at ***C4***, and the rotary magnet (having just moved the wipers to the 11th step) is released at ***G2***. The restoration is held due to the current pulses in its 3 Ω coil, but, when the second P.B.X. level is reached, the *VT* relay operates via the vertical marking bank wipers during the period when the ***V1*** springs are open. *VT* locks on its second coil, and at *VT*1 cuts the vertical drive circuit.

The release of *C* allows relay *E* to operate, and *E* in turn provides a re-operate circuit for *C*.

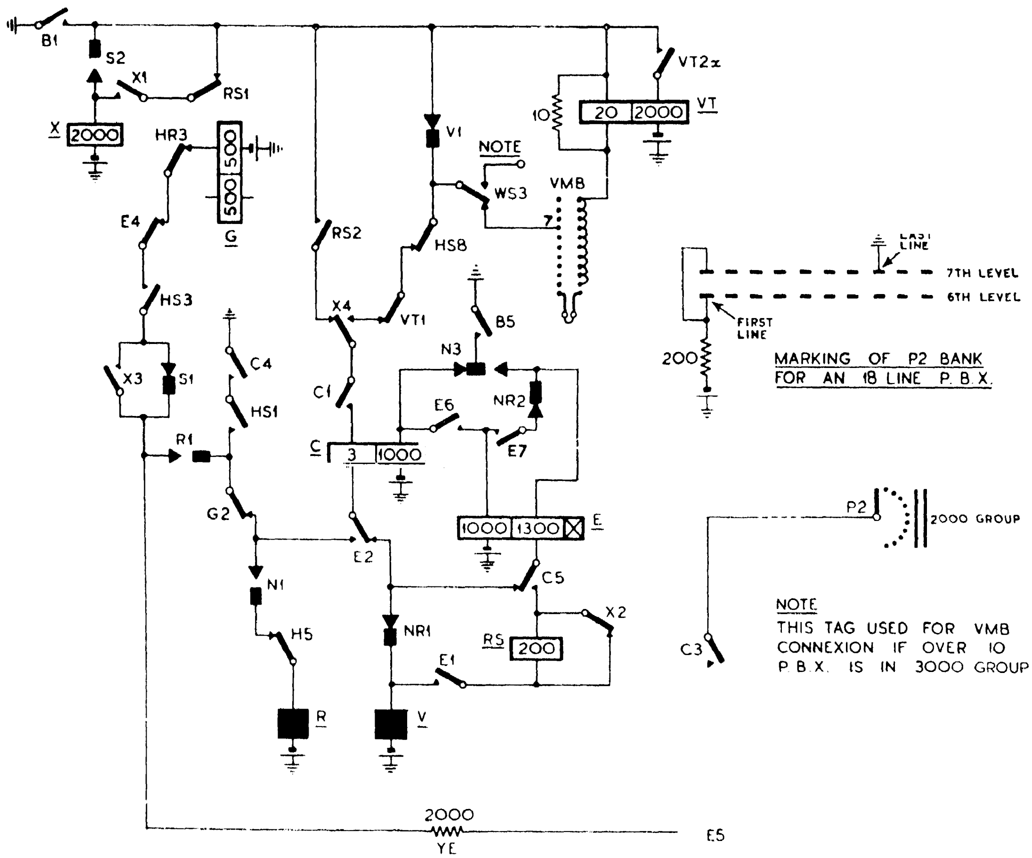


FIG. 490. METHOD OF OBTAINING AUTOMATIC SEARCH OVER THE LINES OF A P.B.X. GROUP WHICH OCCUPIES TWO LEVELS OF THE FINAL SELECTOR

of the rotary armature allows *G* to release at *R*1, and on the release of *G*2 a circuit is provided for the magnet to make the 12th rotary step. The wiper carriage now restores to normal, and all relays (except those which hold independently of the off-normal springs) are released. When the wiper carriage is at its normal position, relays *A*, *B*, and *X* are operated. The *C* relay immediately re-operates to the earth at ***B5***, and a vertical magnet self-interrupted drive circuit is completed from the earth at ***B1*** via *V*1, ***X4*** and the *C* relay. During the vertical drive, relay *C* A circuit is now provided for the *RS* relay from the battery at the vertical magnet via ***E1***, the 1300 Ω coil of relay *E*, to the earth at ***B5***. ***RS1*** releases *X* and the *X*2 contact places a short circuit across the *RS* relay. The *RS* relay is thereby made slow-to-release. The restoration of *X*4 completes the rotary magnet circuit during the release lag of *RS* via the 3 Ω coil of the *C* relay and ***E2***. The rotary magnet circuit is disconnected, and relay *C* releases after the restoration of *RS*2. The circuit is now arranged so that testing conditions are applied to the first line in the new

level. Unless the first contact in the second level is the last outlet to the P.B.X. group, battery potential is applied to the $P2$ bank. Thus, if this first outlet is engaged, P.B.X. hunting takes place in the manner described previously.

Outgoing Junctions. In the earlier exchanges of the No. 14 type most of the junction circuits were arranged for bothway working, but the modern trend is to provide separate outgoing and incoming circuits which can, if necessary, be coupled together to provide bothway working on any particular junction. Outgoing junction circuits can be divided into three broad groups:

(*a*) *Outgoing Junctions to Non-dependent Exchange.* These circuits are designed to provide loop-disconnect dialling over an outgoing junction from the U.A.X., with the usual provision for the repetition of busy flash should the engaged condition be encountered. The circuit includes facilities for receiving the coin-box discriminating signal from the group selector and for passing on suitable signals to the auxiliary multi-metering equipment so that the latter can bar access to multi-fee routes. The circuit provides for the repetition of manual hold signals on calls to manual exchanges.

(*b*) *Outgoing Junctions to Dependent Exchange.* The equipment on an outgoing route to a dependent exchange provides for the repetition of loop-disconnect impulsing, busy flash, manual hold, and route restriction for coin-box lines as in the case of circuits to non-dependent exchanges. In addition, the equipment provides the further facility of repeating trunk offering signals from the parent exchange to the dependent exchange.

(*c*) *Outgoing Junctions to Parent Exchange.* These circuits are somewhat more complex and provide for the transmission of different calling signals to the parent centre, depending upon the discriminating signals received from the group selector. On "9" level calls, conditions are set up for loop-disconnect impulsing to the parent automatic equipment and for the barring of excess fee codes to coin-box subscribers. On "0" level calls, distinctive signals are transmitted over the junction when the call originates from an ordinary or from a coin-box subscriber, so that the call appears on the appropriate calling lamp at the manual exchange. Manual hold is provided on all "0" level calls.

All types of outgoing junction equipment provide for the transmission of signals to the auxiliary equipment to remove all route restrictions on tandem dialled calls. Outgoing junction circuits which incorporate mechanical impulse regenerators are available for use in circumstances where such regeneration is necessary.

Auxiliary equipment can be associated with each individual outgoing junction circuit (when required) to provide fee determination or to apply route restriction as determined by the routing digits dialled by the subscriber. Where the number of codes exceeds the capacity of the individual junction equipment, additional codes can be accommodated by providing common multi-metering relay sets. The circuits of the individual and common multi-metering relay sets are identical to those of the U.A.X. 13 and have already been described in Chapter XV.

Outgoing Junction to Dependent U.A.X. Fig. 491 shows the circuit arrangements of the relay group on an outgoing junction to a dependent U.A.X. The main features of this circuit are:

(*a*) Impulse repetition with a two-stage drop-back feature on the impulsing bridge.

(*b*) Delayed repetition of the busy flash signal as in the standard auto-auto relay set.

(*c*) Metering under the control of an S and Z pulse scheme, the appropriate fees being determined by the auxiliary multi-metering equipment.

(*d*) Repetition of a coin-box barring signal to the auxiliary equipment.

(*e*) Repetition of the trunk offering signal to the dependent exchange.

Relay A operates to the loop extended from the group selector, and at $\boldsymbol{A2}$ operates relay B. $\boldsymbol{B3}$ operates relay BA, and $\boldsymbol{BA2}$ operates relay HA. Contacts $\boldsymbol{HA1}$ and $\boldsymbol{HA2}$ now complete the loop to the outgoing junction, and relay I operates to the loop current.

During dialling, contact $A1$ repeats the impulses to the dependent U.A.X., whilst $A2$ transmits impulses to the counting uniselector of the auxiliary equipment. At the first impulse $A2$ operates relay C, and contacts of this relay operate relays CA and CC. $\boldsymbol{CA3}$ completes the circuit for relay BB, and $\boldsymbol{BB1}$ operates relay MD.

Relay C releases during the intertrain pause, and in turn releases relays CA and CC. $CC3$ applies the marking condition to the auxiliary equipment to operate the appropriate discriminating relays. Relay I (which released during impulsing) now re-operates, and at $\boldsymbol{I2}$ holds relay BB on the release of $CA3$.

This sequence of operations is repeated for each impulse train, and when all digits have been dialled relays A, B, BA, BB, HA, I, and MD are held. When the called subscriber answers, relay D operates to the reversal of current in the forward loop, and at $\boldsymbol{D1}$ operates relay DD and disconnects the circuit of relay MD. Contacts of DD prepare the metering circuit and reverse the line current in the back loop to provide supervisory conditions.

Relay *DA* now operates to the first *S* pulse and prepares the circuit for the operation of relay *DB* to the subsequent *Z* pulse. *DB* now completes the metering circuit, and the appropriate number of pulses is transmitted to the *M*-wire from the auxiliary equipment. Relay *DA* releases at the end of the *Z* pulse, but *DB* remains held for the duration of the call.

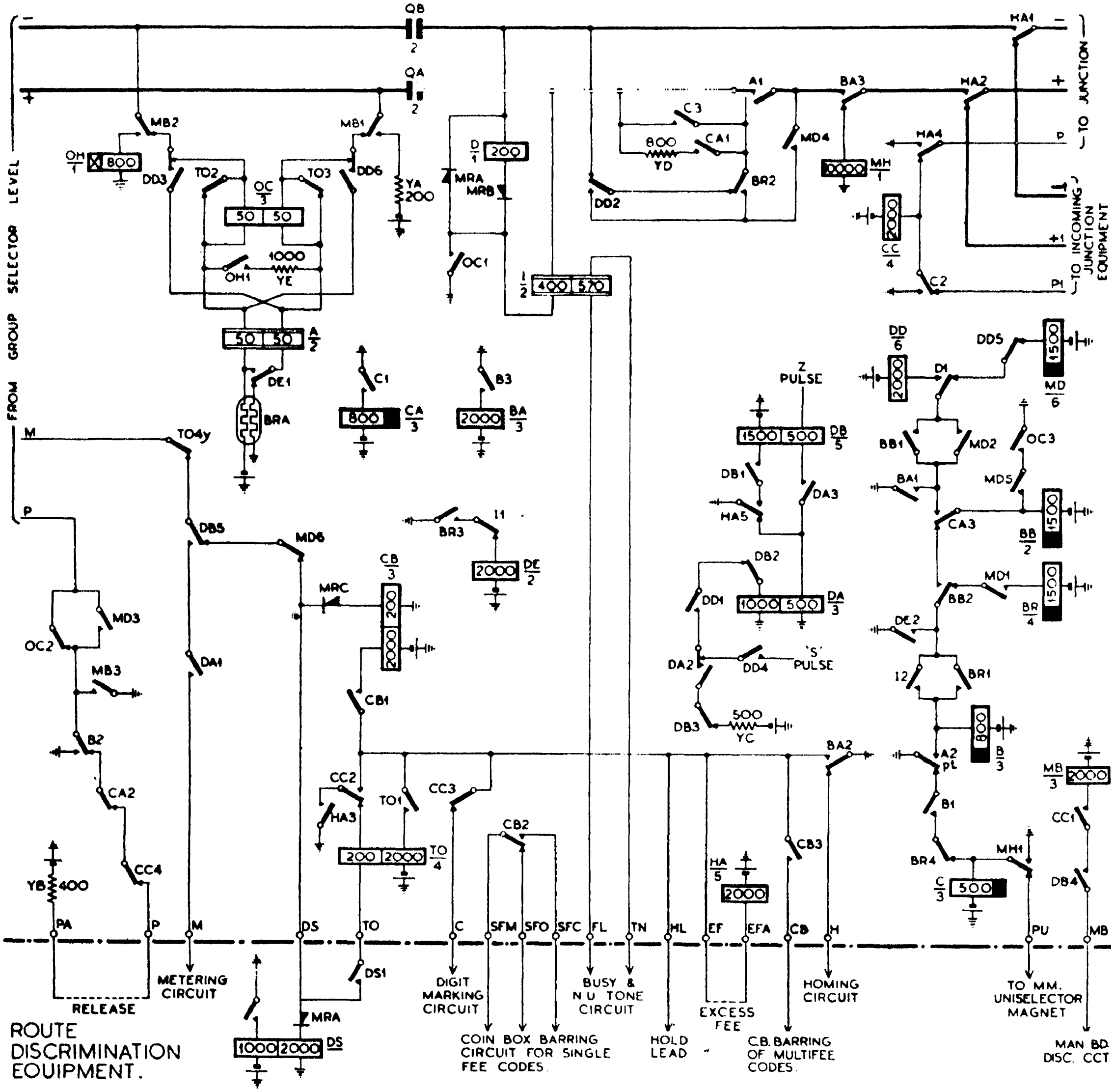


Fig. 491. Relay Group Suitable for use on Outgoing Junctions to a Dependent U.A.X.

If the called subscriber is engaged, the return of busy flash releases relay *I*, and *I* in turn releases relay *BB*. Contact *BB2* prepares for the operation of *BR* when *I* re-operates during the next tone period, and also disconnects the holding circuit for relay *BB*. The next operation of relay *I* operates *BR*. ***BR*1** now provides a holding circuit for relays *B* and *BR*. The next release of relay *I* (i.e. at the next flash period) completes a circuit for relay *DE*, and ***DE*1** repeats the flash signal to the caller.

On calls from the parent operator, relay *TO* is operated to the low resistance + battery extended over the *M*-wire and via the auxiliary equipment. Contacts ***TO*2** and ***TO*3** remove the short circuit from relay *OC* which can now receive

the trunk offering signal from the parent operator. The operation of relay *OC* repeats the trunk offering signal (at ***OC*1**) to the dependent U.A.X., and at ***OC*3** operates relay *BB*. ***BB*2** releases *BR*. At the dependent exchange, the trunk offering signal connects the operator to the required subscriber, and, if the latter agrees to accept the trunk call, the clearance of the local connexion returns a supervisory signal through the U.A.X. 14 to the parent exchange. The repetition of the trunk offering signal to the dependent exchange now completes the ringing circuit for the recall of the required subscriber.

Provision is made for a manual exchange operator to hold the connexion after the calling subscriber has cleared. Earth is applied to the *MB*-lead from the auxiliary equipment when the code for a manual exchange is dialled. Prior to the caller clearing, relays *A*, *B*, *BA*, *BB*, *D*, *DB*, *DD*, *HA*, and *I* are held. When the calling party clears, *A* releases and, by disconnecting the calling loop from the junction, also releases relays *D* and *I*. Contact ***A*2** operates relay *C* and releases relay *B*. *C* in operating energizes relays *CA* and *CC*, whilst *CC* in turn operates relay *MB* to the earth from the auxiliary equipment. ***CC*2** completes a holding circuit for relay *HA* independent of contact ***BA*2**. The operation of contact ***MB*1** applies 200 Ω battery to the + line to repeat the manual hold signal to any intermediate exchanges. Contact ***MB*2** connects relay *OH* to the – line to receive a recall signal from the subscriber. ***MB*3** engages the *P*-wire and holds the preceding selectors.

The release of relay *D* (by contact *A*1) disconnects relay *DD*, and *DD*5 in turn operates *MD*. The release of relay *B* releases *BA*, and *BA* releases *BB* and *MD*. *BA*3 now completes the circuit for the operation of relay *MH* to the battery returned on the + line, and the closure of contact ***MH*1** provides a holding circuit for relay *C* (which would otherwise release following the restoration of *B*1). Relays held at this stage are: *C*, *CA*, *CC*, *DB*, *HA*, *MB*, and *MH*.

If the subscriber recalls, relay *OH* operates to the loop, and at ***OH*1** re-operates *A*. Relays *B*, *BA*, and *BB* now re-operate in sequence, and ***BA*3** reconnects the junction to relays *D* and *I* which operate. ***BB*1** operates relay *DD*. The operation of contact ***BA*3** releases relay *MH*, which at *MH*1 releases *C*. *C* releases *CA* and *CC*, *CA*3 disconnecting the operate circuit of relay *BB* and leaving it dependent upon ***A*2**. *CC*1 releases *MB*, and *MB* restores the *A* relay to the incoming speaking pair. Relay *OH* is now released.

On calls from coin-box subscribers relay *CB* operates to the – battery on the *M*-wire and, at contacts ***CB*2** and ***CB*3**, transmits signals to the auxiliary equipment which provide for the barring of all multi-fee codes. The circuit shown in Fig. 491 is designed for use in conjunction with incoming equipment to provide bothway working. If the junction is taken into use on an incoming call, relay *CC* operates, and at ***CC*4** busies the *P*-wire of the junction on the group selector bank.

The outgoing junction termination for non-dependent routes is substantially similar to the one described above for use on circuits to dependent U.A.X.s. The main difference is the absence of relay *TO* and the associated circuit for repeating a trunk offering signal to the terminal exchange.

Outgoing Junction to Parent Exchange. Fig. 492 shows the circuit arrangements on outgoing parent exchange junctions (where combined "9" and "0" level working is in use). The circuit provides for the repetition of impulses, for busy flash, manual hold, multi-fee metering, etc., for purely auto-auto calls routed via the parent exchange selectors. In addition there are various relays which (in response to discriminating signals received over the *M*-wire) can establish manual calling conditions to route "0" level calls direct to the parent exchange manual board. There are two distinctive manual calling conditions, one for ordinary lines and the second for coin-box lines.

The system of signalling over the parent junctions is identical to that used from U.A.X.s 12 and 13 and has already been described in some detail (see Fig. 417). It will be recalled that:

On "0" Level Calls from Ordinary Subscribers

(*a*) The initial calling condition when the junction is seized is a battery forwarded on the + wire from the U.A.X.

(*b*) When the operator inserts a plug into the answering jack, the current in the + line is interrupted at the manual board termination.

(*c*) This interruption of current causes the application of full earth to the – line from the U.A.X.

(*d*) Receipt of this earth signal at the manual board termination causes the re-establishment of the + line current.

(*e*) The re-establishment of the current in the + line causes the U.A.X. equipment to remove the full earth from the – line and to replace it by an earth connected supervisory relay.

(*f*) When the operator replies, battery is returned over the – wire of the junction to operate the supervisory relay.

On "0" Level Calls from Coin-box Subscribers

(*a*) The initial calling condition is an earth forwarded over the — line of the junction to the parent exchange.

(*b*) When the operator inserts a plug into the answering jack, the — line current is interrupted.

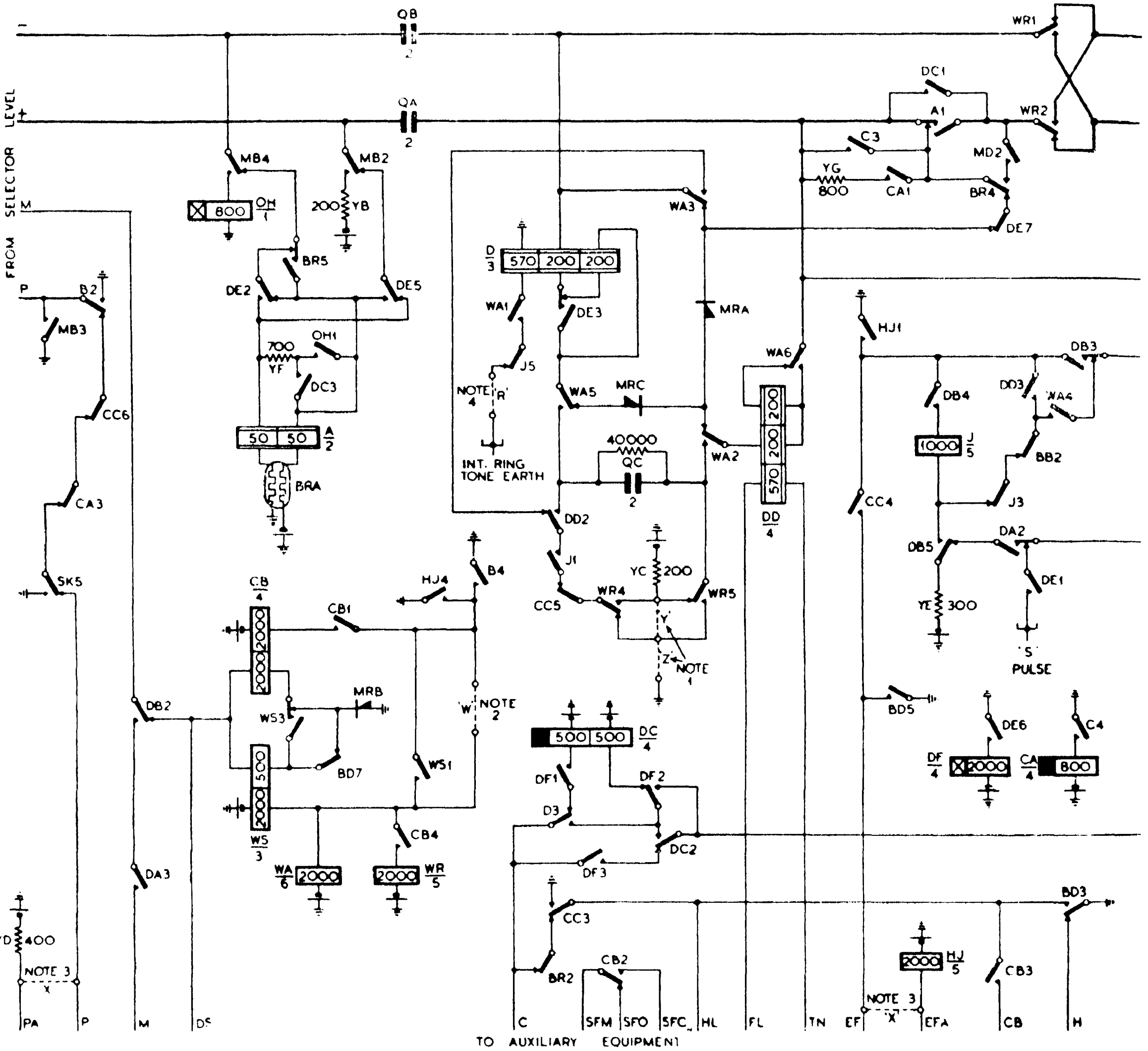


FIG. 492. OUTGOING JUNCTION

battery from the + line and to replace it by a battery connected supervisory relay.

(*f*) When the operator answers, the supervisory signal is an earth returned over the + wire of the junction to operate the supervisory relay at the U.A.X.

(*c*) The interruption of this current causes the U.A.X. equipment to apply battery to the + line.

(*d*) Receipt of this battery at the manual termination causes the restoration of the — line current.

(*e*) The restoration of the — line current causes the U.A.X. equipment to remove the battery from the + line and to replace it by a battery connected supervisory relay.

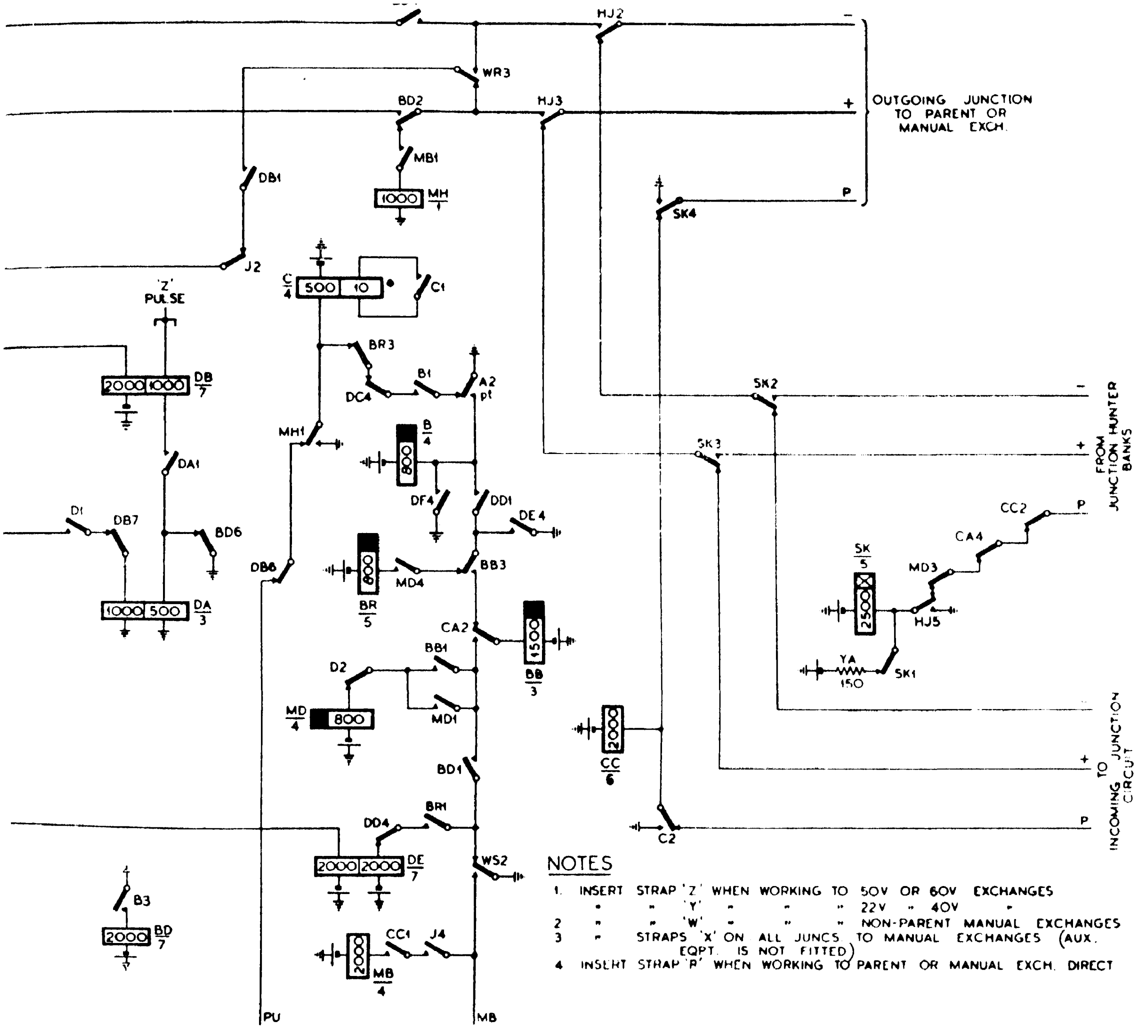
In view of the comparative complexity of the circuit arrangements, it is desirable to consider the operation of the circuit in several stages.

Discrimination and Switching. Fig. 493 shows the basic discrimination and switching arrangements at the U.A.X. end of a parent junction. The circuit operation under the various conditions of

"0" *Level Call from Ordinary Subscriber.* When the junction equipment is seized from a group selector, a "manual call" signal, consisting of a momentary 2000 Ω battery, is applied to the *M*-wire.

Relay *A* then operates to the subscriber's loop, and, at ***A*2**, operates *B*. ***B*2** applies guarding conditions to the *P*-wire, whilst ***B*3** operates *BD*. ***BD*5** in turn operates *HJ* which, at ***HJ*2** and ***HJ*3**, switches the circuit for an outgoing call. At the same time ***HJ*5** disconnects the battery from the *P*-wire of the junction hunters to guard the circuit at this point. Relay *WS* operates to the manual call signal before the circuit is disconnected at ***BD*7**. *WS* locks at ***WS*1**, whilst ***WS*3** removes the rectifier earth from the *M*-wire. The operation of ***WS*1** also provides a circuit for relay *WA*, the contacts of which apply the correct signalling conditions to the outgoing junction.

"0" *Level Call from Coin-box Subscriber.* When the call originates from a coin-box subscriber, the group selector forwards a momentary 150 Ω battery on the *M*-wire. The operation of the circuit is substantially as described above but, in addition, relay *CB* operates to the higher value of current on the *M*-wire. Contacts ***WS*1** and ***CB*4** provide an operate circuit for relay *WR*. Conditions are now established at ***WR*4**, ***WR*5**, ***WA*5**, and ***WA*2**



Circuit for use on Parent Route

for the application of the correct signals on the outgoing junction.

"9" *Level Call from Ordinary Subscriber.* If the call is to be routed via the automatic equipment at the parent exchange, no battery signals are received over the *M*-wire. Relays *A*, *B*, *BD*, and *HJ* operate from the subscriber's loop, but the *WS*, *CB*, *WA*, and *WR* relays remain unoperated. The appropriate loop calling signal is applied to the outgoing junction via *WA*5 and *WA*2.

route is barred to coin-box callers, the auxiliary equipment releases the junction and applies N.U. tone as described above. If, on the other hand, the route is not barred, the circuit behaves as for an ordinary subscriber's "9" level call.

"0" *Level Call from Dependent U.A.X.* If the parent junction is seized by a junction hunter, the *SK* relay operates to earth extended over the *P*-wire. Contacts ***SK*2** and ***SK*3** extend the – and + wires to the outgoing junction. Contact

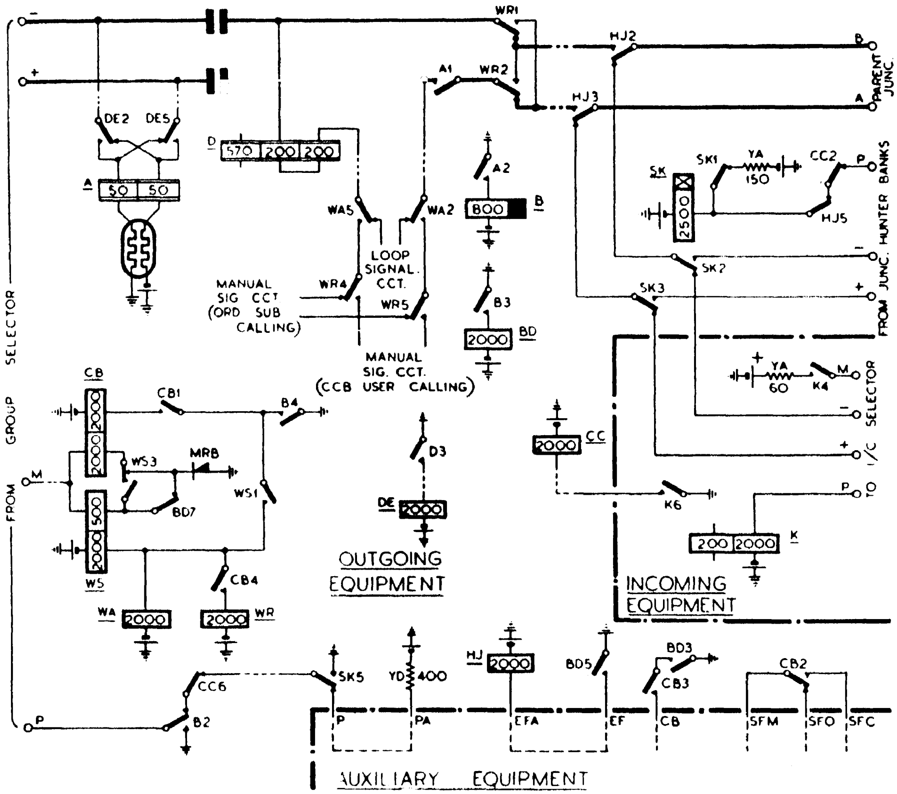


Fig. 493. Main Switching Arrangements of Parent Junction Relay Set

If a spare or unauthorized code is dialled, then the auxiliary equipment (multi-metering or route restricting) disconnects *HJ* and so releases the junction. At the same time N.U. tone is returned to the caller via the tone winding of relay *DD* (see Fig. 492).

"9" *Level Call from Coin-box User.* On such calls a momentary 150Ω battery is applied on the *M*-wire after a short delay period. Relay *CB* operates to this battery and locks at ***CB*1**, but *WS* cannot operate due to the prior operation of ***BD*7**. The operation of the *CB* relay indicates to the auxiliary equipment (at ***CB*2** and ***CB*3**) that the coin-box barring feature is (or may be) required. If the

***SK*5** applies busying conditions to the local group selectors.

Incoming Call from Parent Exchange. When the incoming selector at the U.A.X. (which is individual to the parent junction) receives a calling loop, earth is returned on the *P*-wire to operate relay *K* in the incoming equipment. ***K*6** energizes *CC*, and ***CC*6** in turn disconnects the *P*-wire to engage the junction on the group selector multiple. ***K*4** applies positive battery to the *M*-wire of the incoming selector to prepare for trunk offering and the clearance of restrictions on outgoing routes.

Signalling Arrangements for "9" Level Calls. Fig. 494 shows the detailed signalling elements

on calls to the parent exchange automatic equipment.

"9" *Level Call from Ordinary Subscriber.* On receipt of the calling subscriber's loop, relays *A*, *B*, *BD*, and *HJ* are operated as previously described. The other relays remain normal in the absence of a discriminating signal on the *M*-wire. It will be recalled that loop calling (followed by loop-disconnect impulsing) is used on calls to the parent automatic equipment. The initial loop is completed at the U.A.X. via **A1**, *WA*6, the *DD* relay, *WA*2, *MRA*, and *WA*3.

end of the impulse train—but this feature has been omitted from Fig. 494 to avoid confusion.)

At the end of each digit, relays *C* and *CC* release, *CC*3 reconnecting earth to the *C*-wire of the auxiliary equipment to mark the end of the digit.

When the called party replies, the line current is reversed from the parent exchange, and relay *D* operates. **D3** completes a circuit for *DC*, and **DC2** in turn operates *DE*. Contacts **DE2** and **DE5** (see Fig. 493) reverse the line current towards the calling party.

The operation of **DE1** starts the standard meter-

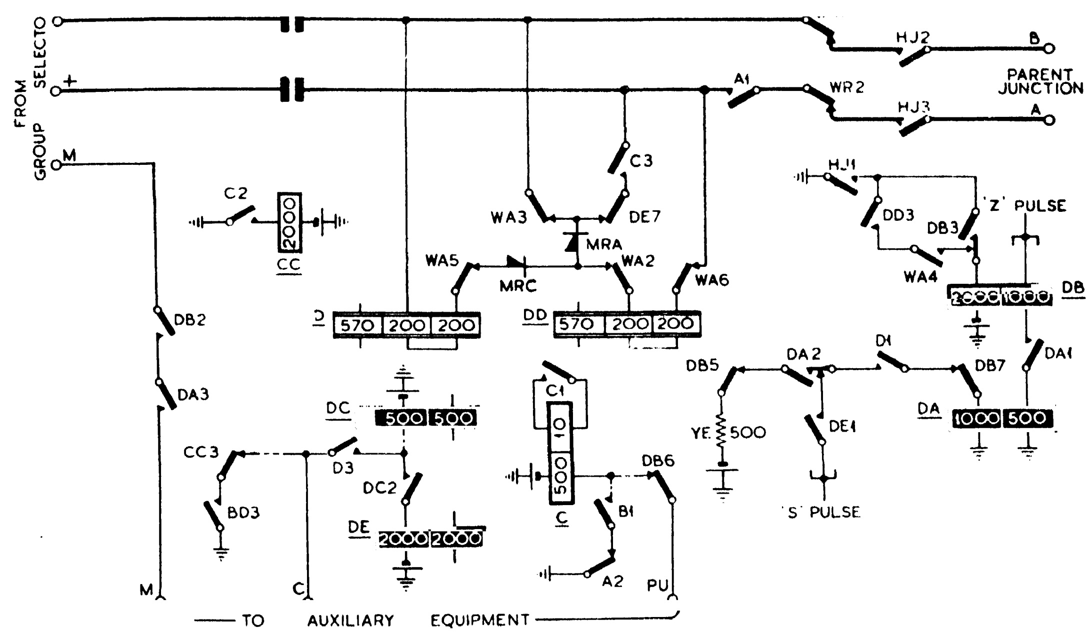


FIG. 494. JUNCTION SIGNALLING CONDITIONS ON "9" LEVEL CALLS

Relay *DD* operates to the loop current, but **DD3** cannot pre-operate *DB* on this occasion due to the fact that *WA*4 is normal. The circuit is therefore available to receive a metering signal.

The *A*1 and *A*2 contacts respond to the impulses dialled by the calling subscriber. *A*1 repeats the impulses over the junction to the parent exchange, whilst *A*2 sends impulses over the *PU*-wire to the auxiliary equipment. At the first release of *A*2, relay *C* operates and holds until the end of the impulse train due to the short circuit across its 10 Ω winding. Contact **C3** short-circuits the *DD* relay and rectifier to exclude these components from the junction impulsing circuit. **C2** operates *CC* which, at **CC3**, removes the earth from the *C*-wire of the auxiliary equipment. (The *C* relay also operates the slugged relay *CA* which is required to give the two-stage drop-back at the

ing cycle, i.e. a circuit is completed for the operation of *DA* on the first *S* pulse. **DA2** provides a temporary holding circuit for *DA*. In due course relay *DB* operates to the *Z* pulse, and relay *DA* holds over the same circuit. During the time of the *Z* pulse, the appropriate number of meter pulses is transmitted from the auxiliary equipment via **DA3** and **DB2** to the *M*-wire. At the end of the *Z* pulse, *DA* releases but *DB* holds via **DB3** so that metering cannot be re-established during the period of the call.

"9" *Level Call from Coin-box Subscriber.* The operation is as described above, except that relay *CB* is also operated when the junction equipment is seized by the group selector. The operation of *CB* provides the necessary conditions to the auxiliary equipment to bar the caller from any excess fee routes.

Signalling Circuit for "0" Level Calls. Fig. 495 shows the more detailed signalling circuits for calls to the parent exchange manual board.

"0" *Level Calls from Ordinary Subscriber.* On receipt of the caller's loop and of the "manual call" signal, relays *A*, *B*, *BD*, *HJ*, *WS*, and *WA* are operated as already explained. Ringing tone is returned by the operation of ***WA*1**, whilst the battery at *YC* is extended to the *A*-wire of the junction by ***WA*2** and ***WA*6**. Relay *DD* operates in series with this calling signal, and at ***DD*3** operates relay *DB* to the earth at ***HJ*1**. *DB* locks at ***DB*3**. Relays *DA* and *DB* are associated with the metering, and the operation of *DB* on an

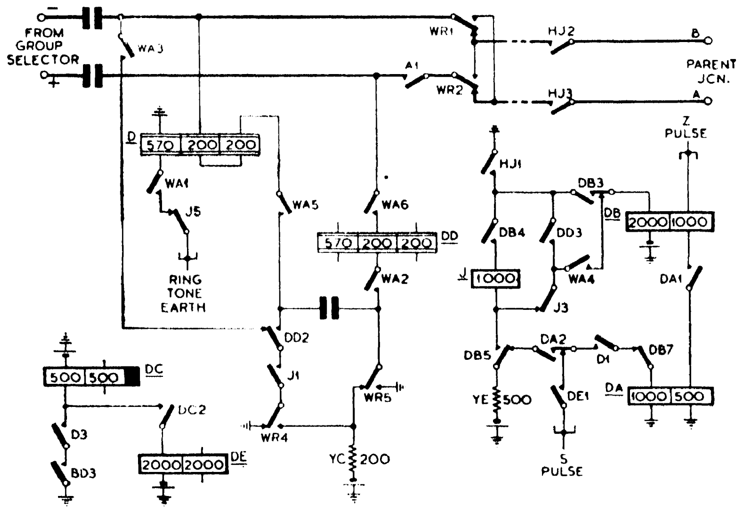


FIG. 495. JUNCTION SIGNALLING CIRCUIT FOR "0" LEVEL CALLS

"0" level call ensures that *DA* cannot operate to the *S* pulse at a later stage, thereby preventing metering on manual board calls.

The 200 Ω battery extended on the *A*-wire causes the calling lamp to light at the parent exchange and, when the operator inserts a plug in the answering jack, the consequent disconnexion of the + wire releases relay *DD*. *DD*3 now removes the short circuit from relay *J*, and the latter operates via ***DB*4** and ***DB*5**. ***J*3** prevents the release of relay *J* on a subsequent operation of the ***DD*3** contact. ***J*5** disconnects the ringing tone. The operation of ***J*1** extends earth from *WR*4 via *DD*2 and ***WA*3** to give the "earth on *B*-wire" signal to the parent exchange. The parent exchange equipment now restores the + wire and allows relay *DD* to re-operate. ***DD*2** switches the *D* relay into the *B*-wire signalling circuit in readiness for the reception of the answering signal from the parent exchange.

When the parent exchange operator throws the speaking key, a battery on the — wire is returned to the U.A.X. This supervisory signal operates relay *D* in the U.A.X. equipment, and ***D*3** in turn energizes *DC*. ***DC*2** completes a circuit for *DE*, whilst ***DE*2** and ***DE*5** (see Fig. 493) reverse the line current in the calling loop. (This signal is, of course, required to darken the supervisory lamp at any remote manual exchange which interdials through the U.A.X. 14.)

"0" *Level Call from Coin-box User.* It has been explained that when an "0" level call originates from a coin-box telephone, relays *A*, *B*, *BD*, *HJ*, *WS*, *WA*, *CB*, and *WR* are operated. ***WR*5** now replaces the calling battery at *YC* by a full earth, whilst ***WR*4** replaces the earth (which is forwarded over the *B*-wire on calls from an ordinary subscriber) by the battery condition at *YC*. At the same time contacts ***WR*1** and ***WR*2** reverse the + and — wires so that the signals are now given in the C.C.B. order of presentation (i.e. earth on — wire to call, battery connected supervisory relay on + wire later.)

Incoming Junctions. The incoming junction circuits at a U.A.X. 14 are of three main types:

(1) *Incoming Junction from Parent Exchange.* This circuit is designed for direct connexion to a 1st selector and includes facilities for the return of busy tone and flash to the caller if dialling should commence before the 1st selector is ready to receive the initial impulse. The circuit also provides for the forwarding of a discriminating signal to prepare the final selector for trunk offering to a local subscriber, or to prepare an outgoing junction relay set for the re-transmission of the trunk offering signal to a dependent exchange. The same signal also gives access to outgoing junction routes which are barred to local subscribers.

(2) *Incoming Junction from Non-dependent Exchange.* This circuit includes a selector hunter, by means of which access is obtained to the common group of 1st group selectors. As in the previous circuit, busy tone and flash are returned to the caller under premature dialling conditions. The equipment provides for a discriminating signal to give access (on tandem calls) to those routes which are barred to local subscribers by the route discriminating equipments.

(3) *Incoming Junction from Dependent Exchange.* This circuit is somewhat more complex than the two previous circuits. It provides access to the

local switching train at the U.A.X. 14 via a selector hunter with the usual provision for the return of engaged conditions should premature dialling occur. In addition the circuit is arranged so that, if a caller on the dependent exchange dials "0," he is automatically routed (via a junction hunter) to a parent exchange junction. The same uniselector mechanism is used both to provide the junction hunter on "0" level calls, and the selector hunter on auto calls which are to be completed through the U.A.X. equipment. A distinctive signal is given to the parent manual board on "0" level calls from coin-box subscribers.

Incoming Junction from Parent Exchange. Fig. 496 shows the circuit arrangements of the terminal equipment on an incoming junction from the parent exchange. If the parent exchange is of the C.B. type (22 or 40 V) the calling condition is a battery signal on the + line which operates relay *LA*. ***LA*1** then connects relay *L* to the – line, and this relay operates in series with the equipment at the distant exchange. ***L*1** operates relay *B*, and ***B*3** in turn operates relay *K* to the battery on the *P*-wire from the 1st group selector. ***B*4** earths the *P*-wire of the selector multiple if

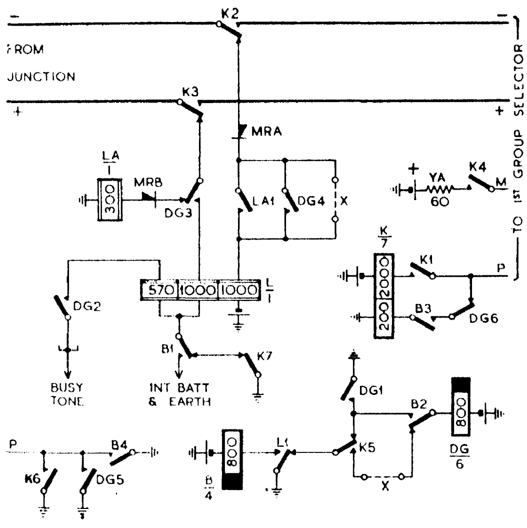


FIG. 496. INCOMING JUNCTION CIRCUIT FROM PARENT EXCHANGE

the junction is arranged for bothway working. The operation of ***K*2** and ***K*3** extends the calling loop to the 1st selector, and relays *L* and *LA* release. ***K*4** extends the + battery signal to the *M*-wire in preparation for trunk offering or route unbarring.

Relay *L*, in releasing, breaks the circuit for relay *B*, and when *B* restores a circuit is provided for relay *DG*. Contact ***DG*5** now provides an additional guard on the *P*-wire of the outgoing portion of the circuit.

The battery and earth conditions from the manual exchange are changed to loop calling conditions on receipt of the battery condition from the U.A.X.

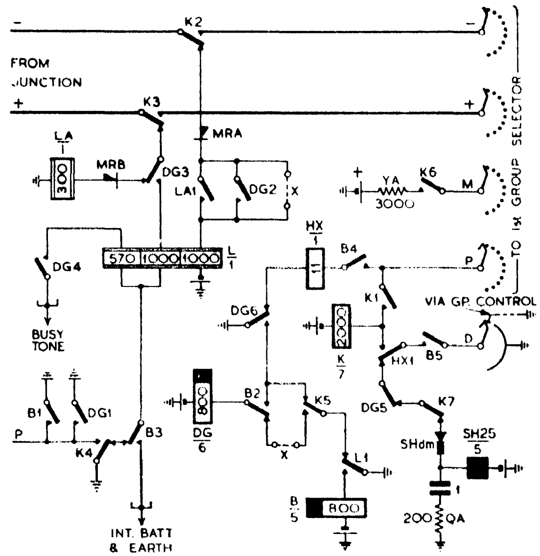


FIG. 497. INCOMING CIRCUIT ON JUNCTIONS FROM NON-DEPENDENT EXCHANGE

on the – wire. If the parent exchange is of the sleeve control type, the initial calling signal is a loop. In these circumstances, straps *X* are inserted.

If the first impulse train arrives before relay *K* has operated, relay *L* responds to the first impulse and at *L*1 operates relay *DG*. ***DG*2** and ***DG*3** return busy tone and flash to the caller, and also release relay *LA*. ***DG*4**, however, maintains the holding circuit for relay *L* on calls from C.B. exchanges. ***DG*6** disconnects the operate circuit for relay *K* to prevent switching to the group selector. An additional contact, ***DG*5**, maintains the guard on the outgoing *P*-wire until relay *DG* restores to normal when the call is abandoned. Rectifiers *MRA* and *MRB* assist in the prevention of false operation of relays *L* and *LA* which may occur due to differences of battery and earth potential at the two exchanges.

The circuit illustrated in Fig. 496 can also be used for the termination of incoming junctions from a dependent manual exchange, or for a non-dependent exchange when it is desirable to provide direct access to a 1st selector.

Incoming Junction from Non-dependent Exchange. Fig. 497 shows a somewhat similar circuit suitable for use on an incoming junction from a non-dependent automatic or manual

exchange, or from a dependent manual exchange. The main difference is the inclusion of a 5-level uniselector which serves as a selector hunter on receipt of a calling condition.

Relays L and LA operate to the calling con-

Contacts **K2** and **K3** extend the calling loop to the group selector and at the same time disconnect the holding circuit of relays L and LA. **K6** extends + battery via 3000 Ω to provide "route unbarring" on tandem calls.

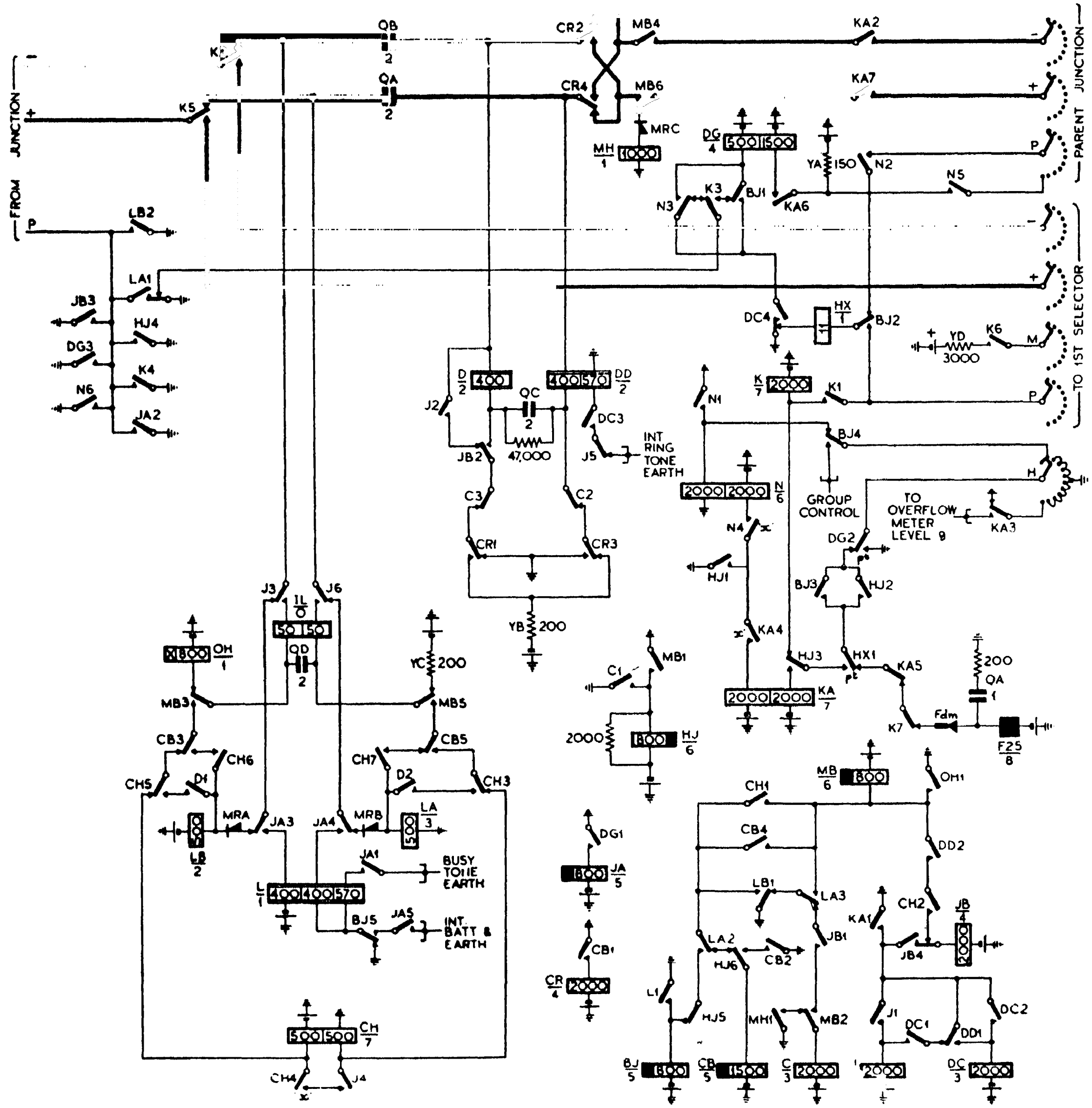


FIG. 498. INCOMING JUNCTION CIRCUIT FROM DEPENDENT U.A.X.

dition on the junction as already described, and **L1** operates relay B. **B1** guards the outgoing portion of the circuit against intrusion, whilst **B5** completes the drive circuit of the (non-homing) selector hunter Relay HX operates when a free 1st selector is found, and **HX1** completes a circuit for relay K and disconnects the uniselector drive.

The return of earth on the P-wire from the group selector now releases relay HX and provides a holding circuit for relay K for the duration of the call.

If impulsing commences before relay K switches (i.e. before the selector hunter seizes a free 1st selector) relay L responds to the first break, and

at $L1$ operates *DG*. Contacts of *DG* return busy tone and flash as before. ***DG*5** disconnects the selector hunter drive, whilst ***DG*6** prevents relay *HX* from operating when the selector on which the wipers are standing becomes free.

Incoming Junction from Dependent U.A.X. Fig. 498 shows the more complicated circuit arrangements required on an incoming junction from a dependent U.A.X. The main features of this circuit are the arrangements for repeating "0" level calling signals from the dependent exchange to the parent manual board, and the use of a single 8-level uniselector which serves both as a selector hunter (on tandem auto calls) and as a junction hunter (on "0" level calls).

If the junction signals indicate that the call is to be routed to the automanual switchboard, this uniselector functions as an "0" level hunter by driving to contact No. 1 and then hunting over the junction group. If, on the other hand, the signal from the dependent U.A.X. is a loop, the uniselector becomes a selector hunter. If the uniselector is camping on a trunk leading to a disengaged local group selector, switching proceeds without hunting, but if this trunk is engaged, the uniselector hunts over the available outlets to group selectors. It should be noted that the uniselector behaves as a homing type mechanism on parent junction calls, but as a non-homing selector on automatic calls.

"0" *Level Call from Ordinary Subscriber at Dependent U.A.X.* In this case the calling signal over the junction is a battery on the + wire, which operates relay *LA* in the U.A.X. 14 termination (Fig. 499). ***LA*1** engages the junction (if bothway) on the group selector multiple. ***LA*3** operates *MB* and ***MB*1** in turn completes the circuit for relay *HJ*. The closure of ***HJ*2** completes a homing circuit for the uniselector, which now rotates until it reaches the first contact. When this position is reached, relay *N* operates from the battery at the uniselector driving magnet, locks at ***N*4**, and at ***N*2** applies the testing relay *HX* to the *P* wiper of the parent exchange junction hunter. At the same time ***N*1** re-establishes the magnet drive circuit so that the uniselector hunts automatically over the parent exchange group until a free circuit is found. Relay *HX* now operates to the free battery condition on the *P*-wire and disconnects the drive at ***HX*1**. At the same time a circuit is completed for relay *KA* to the earth on the homing arc, and on operation this relay holds via ***KA*4**. ***KA*5** isolates the uniselector driving magnet against the imminent release of *HX*1. (The *HX* relay releases when the parent exchange junction equipment removes the free battery from the *P*-wire.) The caller is now

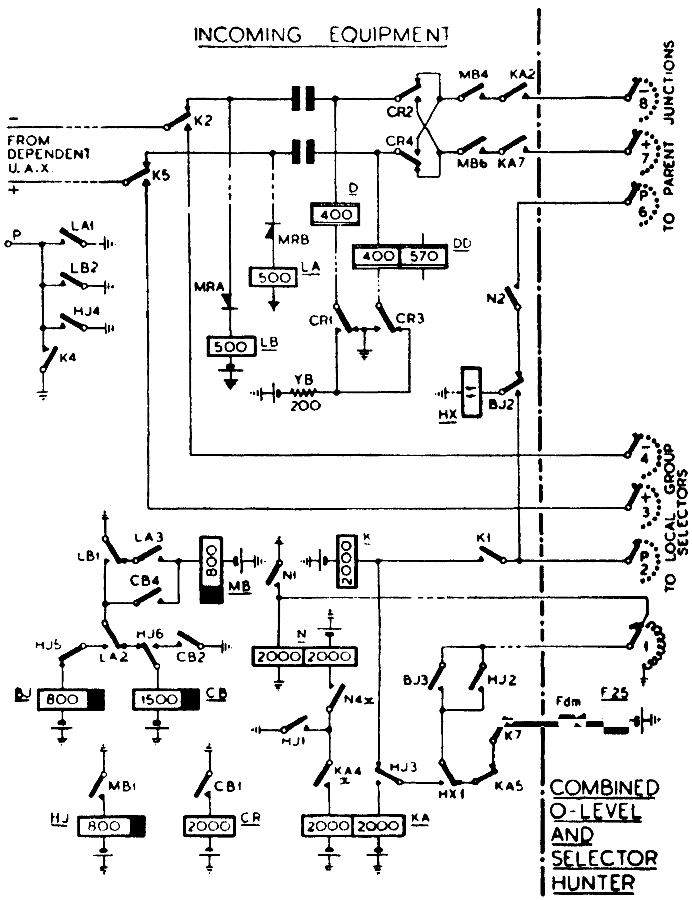


Fig. 499. Main Signalling and Switching Scheme of Dependent Junction Termination

extended to the parent exchange by contacts ***KA*2** and ***KA*7**. The signalling condition (battery on the + wire) from the dependent exchange is now repeated to the parent exchange by the battery at *YB* which is applied to the + wire via one coil of *DD* and the various operated contacts.

"0" *Level Call from Coin-box Subscriber at Dependent U.A.X.* It has been seen that, when such a subscriber dials "0," an earth is extended on the — wire towards the parent exchange. Such a signal operates relay *LB* at the U.A.X. 14 (Fig. 499)

and ***LB*2** engages the circuit (if bothway) on the group selector multiple. ***LB*1** energizes the *CB* relay, and the ***CB*1** contact in turn operates the *CR* relay. Contacts ***CR*2** and ***CR*4** reverse the + and — wires of the junction, whilst ***CR*1** and ***CR*3** operate to give the required signalling earth on the — wire to the parent exchange. The closure of ***CB*4** provides a circuit for the *MB* relay, which in turn operates *HJ*. The *CB* relay holding circuit is now transferred to the control of the *HJ* relay. The operation of *HJ* causes the uniselector to drive to contact 1, and the switch then

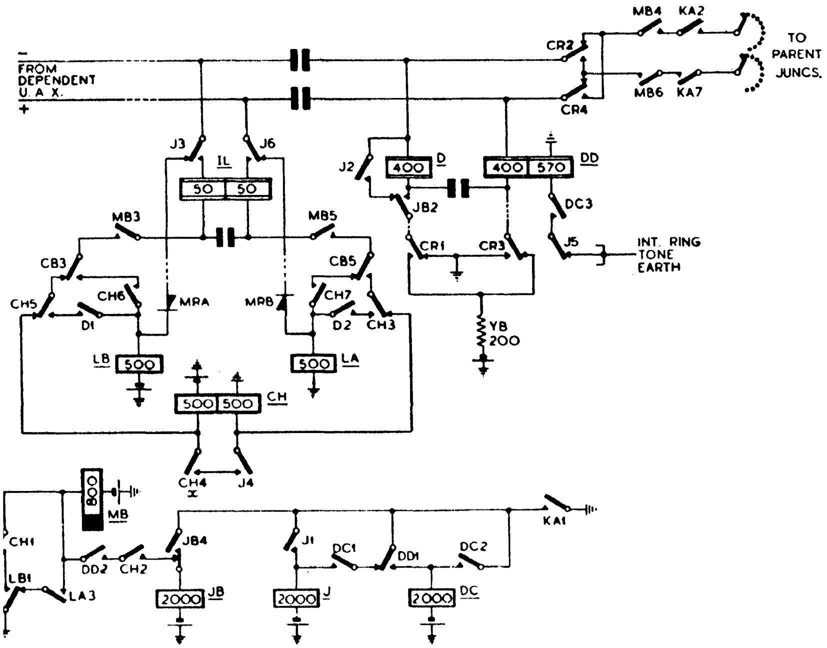


FIG. 500. REPETITION OF "0" LEVEL SIGNALS

unts over the junction group as previously described.

It is important to note that, when a U.A.X. 14 acts as a tandem exchange for the "0" level traffic from a dependent U.A.X., only one digit (0) is required to route the caller to the parent exchange operator.

"9" *Level Call from Dependent U.A.X.* On receipt of the loop calling signal from the dependent U.A.X. (indicating that a call to the parent exchange automatic equipment is required) relays *LA* and *LB* operate. ***LA*1** and ***LB*2** apply the necessary busying signals to the U.A.X. 14 selectors, whilst ***LB*1** and ***LA*2** complete a circuit for relay *BJ*. ***BJ*2** extends the testing relay *HX* to the *P*-wire of the selector hunter, whilst the drive circuit of the latter is completed at ***BJ*3**. The uniselector now behaves as a selector hunter and, if the outlet on which the wipers are standing is engaged, the uniselector drives in search of a free selector. When a free condition is encountered, relay *HX* operates and cuts the drive at ***HX*1**. The same contact completes a circuit for relay *K*, and the loop from the dependent exchange is extended to the group selector at contacts ***K*2** and ***K*5**. In due course an earth is returned from this selector to hold relay *K* via contact ***K*1**. Relays *LA*, *LB*, and *BJ* are now released.

"0" *Level Signal.* Fig. 500 shows in more detail the signalling circuits involved when a U.A.X. 14 acts as tandem exchange for an "0" level call from a dependent U.A.X. It will be recalled that the standard signalling conditions on an "0" level call from an ordinary subscriber at a U.A.X. are:

(*a*) Battery forwarded from the U.A.X. on the + wire causes the calling lamp to glow at the parent exchange.

(*b*) When an answering plug is inserted in the jack, the + wire is disconnected at the parent termination.

(*c*) The interruption of the current on the + wire causes the U.A.X. termination to forward earth on the — wire. This signal restores the + wire and disconnects the — wire at the parent termination.

(*d*) When the operator throws the speak key (and when the called party replies) battery is returned on the — wire to the U.A.X.

It is clear that the circuit at an intermediate U.A.X. must be capable of repeating these signals in both directions.

"0" *Level Call from Ordinary Subscriber.* The transmission of a battery on the + wire from the dependent U.A.X. causes the operation of relays *LA*, *MB*, *HJ*, *N*, and *KA* at the intermediate U.A.X. as previously described. During this sequence of operations, a junction to the parent exchange is seized and the initial calling signal (battery on + wire) is repeated on the outgoing junction to the parent exchange. This causes the "ordinary" calling lamp to glow. Relay *DD* operates in series with the signalling current and ***DD*1** completes a circuit for relay *DC*. ***DC*3** applies ringing tone to the calling party. When the parent operator inserts an answering plug, the disconnexion of the + wire releases relay *DD*, and the restoration of *DD*1 allows relay *J* to

operate from the earth at **KA1**. **J5** disconnects the ringing tone, whilst **J6** disconnects the + wire back to the originating U.A.X. (Relay *LA* releases as the result of this disconnexion, but the slow-to-release feature of *MB* enables the latter relay to hold pending the imminent re-operation of *LA*.) At the same time contact **J2** forwards an earth on the − wire to the parent exchange to simulate the condition which is received almost immediately from the dependent U.A.X. This signal from the dependent U.A.X. operates relay *CH* in the U.A.X. 14 termination, and *CH* locks at **CH4**. **CH7** restores the continuity of the + wire back to the dependent U.A.X. and relay *LA* is re-energized. At the same time the − wire to the dependent exchange is disconnected at *CH5*.

Receipt by the parent exchange of the earth on the − wire causes the restoration of the + wire and the disconnexion of the − wire. The former allows relay *DD* to re-operate and **DD2** now provides a circuit for *JB*. **JB2** connects the *D* relay to the − wire of the parent junction circuit in readiness for the receipt of the supervisory signal. The operation of the parent exchange operator's speak key returns battery on the − wire to the U.A.X. 14, and operates relay *D*. The signal is repeated to the dependent U.A.X. by contact **D1**. The supervisory signal is withdrawn when the operator restores her speak key, but is re-established when the called party replies.

"0" *Level Call from C.C.B. Line at Dependent Exchange.* The operation of the U.A.X. 14 equipment is similar to that described above, except that the operation of relay *CR* re-arranges the signals to the parent exchange.

Common Services and Power Plant. The power installation of a U.A.X. 14 is normally of the parallel battery float type described in Chapter XXVII. Ringing, tones, and certain earth pulses are derived from a ringing machine of normal design, an automatic changeover circuit and a reserve battery-driven ringing being provided for use in the event of a failure of the public supply mains. Other earth pulses (1 sec, 30 sec, etc.) are obtained from a battery-driven electric clock.

Unlike the smaller U.A.X.s, arrangements are provided for the extension of urgent alarms to the parent centre. The throwing of an alarm extension key on the D unit disconnects the local alarm lamps and buzzer. If an urgent alarm should occur whilst the system is extended, an earth signal is transmitted on a pre-determined junction to operate alarm equipment at the parent exchange. The alarm extension key is also arranged to intercept the line to the service telephone at the U.A.X. If the service number is dialled whilst the alarms are extended, the caller receives N.U. tone, thereby making it possible to check from the parent or from any other point whether the alarms have been extended. A further safeguard against failure to extend the alarms is provided by an alarm lamp near the door of the exchange, which glows whenever the alarm extension key is normal.

Obsolescent Types. The U.A.X. 14 supersedes U.A.X. types Nos. 7 and 9, but there are a few of the obsolescent systems still in use.

U.A.X. No. 7. The U.A.X. 7 is often known as the A.G.S. System, since it was designed by co-operation between Messrs. Automatic Telephone and Electric Company, Messrs. General Electric Company, and Messrs. Siemens Brothers. Like the U.A.X. 14, the No. 7 system provides for a maximum of 800 subscribers' lines. The U.A.X. is built up of a number of standardized racks which are interconnected via connexion strips. The original design provided for the enclosure of each unit in airtight cabinets so that the equipment could be installed in unheated buildings, but it was later found that it was preferable to provide heating, which obviated the necessity for enclosing the apparatus racks. The units are of 5 standard types:

A Unit. 100 calling equipments, linefinders, and final selectors.

B Unit. A 1st selector unit.

C Unit. A selector and junction unit.

D Unit. Junction and multi-metering equipment.

E Unit. Junction equipment.

A 4-digit numbering scheme is employed with 2-motion linefinders, 1st selectors and final selectors. The subscribers' numbering range is 2000–2399, and 3000–3399, with 1st selector absorption if the initial digit is 2 or 3. The U.A.X. 7 provides combined "0" and "9" level working, tandem facilities, trunk offering facilities and, in some cases, multi-metering facilities. The final selectors will accommodate P.B.X. groups. A feature of the No. 7 system is the absorption of an initial digit 1 by the local 1st selectors. This provides an additional level which can be used for giving access to subscribers' lines. The final selectors are of the 200-outlet type, and on local calls the 1st selector discriminates on the first digit (2 or 3) and passes a signal forward to the final selector to switch the call to the appropriate 100-line group. The transmission bridge is accommodated in the 1st selector, and the circuit is arranged so that this same selector supplies ringing current if the called subscriber is free. If the

called subscriber is engaged, the engaged signal is returned from the 1st selector and the final selector is released.

U.A.X. No. 9. The U.A.X. 9 (Bypath type S) is made up of three types of unit:

A Unit.	100-line subscribers' unit.
B Unit.	A selector unit.
C Unit.	A junction unit.

All switches are of the 50-point Bypath type, whilst a 3-digit numbering range (200–299) is adopted for local subscribers. The U.A.X. employs 1st and 2nd linefinders and a selector which gives access via the 1st linefinder to the called subscriber. The U.A.X. gives standard "0" level facilities with combined "0" and "9" level working to the parent exchange. One or two digit dialling codes can be used for giving access to adjacent exchanges, whilst facilities are provided for tandem dialling, for trunk offering, and for P.B.X.s.

EXERCISES XVI

1. Give a simple diagram to show the trunking arrangements of local calls at a U.A.X. 14. What are the advantages of a 4-digit numbering scheme, and how is it possible to provide for such a scheme with only one group selector stage?

2. Explain, with the aid of suitable circuit elements:

(*a*) How local traffic is routed via directly-connected linefinders until all such circuits are engaged and then to linefinders which are indirectly connected to group selectors.

(*b*) What happens when a subscriber originates a call if all the group selectors to which he has access are engaged.

(*c*) What happens if the control relay set which serves a particular linefinder group becomes faulty.

3. At a unit automatic exchange, levels 1, 2, 3, and 0 of the 1st group selectors are connected to four groups of 200-outlet final selectors. With the aid of a diagram, describe the operation of a first group selector when the first digit train (2 or 3) of a local subscriber's number is dialled. What happens if the second digit train is received before the group selector has released fully? (*C. & G. Telephone Exchange Systems II*, 1947.)

4. Draw the circuit arrangements which make it possible for a final selector at a U.A.X. 14 to search over a P.B.X. group of 20 lines.

5. A certain final selector group at a U.A.X. 14 has 150 working subscribers, and a total of 19 final selectors are provided to carry the incoming traffic. Consideration is being given to a proposal to add a large P.B.X. of 20 lines to this group. It is estimated that the incoming traffic to the P.B.X. will be 7·5 T.U. Can the P.B.X. be added without adversely affecting the grade of service in the group? If so, how many final selectors would be required to carry the total traffic of the augmented group?

6. Describe the general arrangements and the equipment of the standard units used in a U.A.X. 14. Give an approximate floor plan to show the lay-out of equipment at a 600-line exchange. It may be assumed that the junction terminations require 5 units.

7. Sketch the trunking arrangements for junction traffic at a U.A.X. 14. Explain:

(*a*) Why the parent junctions are terminated directly on group selectors whilst non-parent routes are given access via selector hunters.

(*b*) Why selector hunters are necessary on some incoming junctions in view of the fact that the number of junctions provided is usually only sufficient to carry the busy hour traffic.

(*c*) What you think are the merits of using selector hunters in a U.A.X. 14 as compared with the termination of the junctions on the banks of linefinders (as in the U.A.X. 13).

8. Describe, with the help of simple diagrams, how the outgoing equipment on the parent route can distinguish between "9" level calls and "0" level calls from ordinary and coin-box subscribers. Explain concisely any timing requirements of the discriminating signals, and the reasons for such requirements.

9. What happens in a U.A.X. 14 if

(*a*) an ordinary subscriber dials a spare single digit junction code;

(*b*) a coin-box subscriber dials "9" when the parent exchange is beyond unit-fee radius of the U.A.X.

(*c*) any subscriber dials a local number on an unequipped final selector group?

10. Compare the testing circuit of a group selector at a U.A.X. 14 with that of the standard group selector used in a non-director exchange. What are the relative merits of the two systems of testing?

CHAPTER XVII

COMMUNICATION BETWEEN AUTOMATIC AND MANUAL EXCHANGES

THE conversion of a complex and extensive telephone network from manual working to automatic switching may take a considerable number of years to complete. During the transition period facilities must be provided for the completion of traffic between the subscribers connected to automatic exchanges and those still on the older manual systems. Generally speaking, the order of conversion of the individual exchanges of a network is determined by such matters as exhaustion of the manual equipment, the available accommodation, the economics of maintaining the old plant, and many other similar factors. Thus, it is not practicable (except in certain large towns and cities) to automatize the network district by district. During the transition period the automatic and manual exchanges are intermixed in such a way that facilities are required at most exchanges for dealing with traffic to nearby exchanges which are working on the alternative system.

Even when all exchanges of a system have been converted to automatic switching, it is still necessary to retain a certain number of manual switchboards for the handling of assistance traffic and for dealing with calls which are beyond the dialling range of the subscribers. It is possible that in the comparatively near future the range of subscriber dialling may be increased, so that fewer and fewer calls need be routed through the automanual switching centre. It will, however, always be necessary to retain manual switching points throughout the network for dealing with inquiries, subscribers' difficulties, calls from coin-box telephones, and so on.

It is the purpose of this chapter to examine the various problems associated with the handling of traffic between manual and automatic exchanges, and to describe some of the more common signalling and switching methods.

Dialling-out. The dialling by a subscriber (or operator) of one or more code digits (except 0 or a recognized service code) to gain access to an operator is known as *dialling-out* (or "dials operator"). Such calls may be routed from the selector levels at the originating exchange over a direct junction to the manual switchboard, or, in some cases, the call may be routed via one or more intermediate automatic exchanges. (It should be noted that on calls from an operator to an automatic subscriber the process is known as *direct dialling* ("dials auto") or *interdialling* ("dials tandem"), depending upon whether or not the call is routed through intermediate automatic plant.)

Direct access from selector levels to a nearby manual exchange is usually provided when the volume of traffic from the automatic subscribers justifies the provision of a direct route to the manual exchange. In some cases it may also be desirable to provide a direct route from the automanual switchboard to the manual exchange, but in other circumstances calls from the automanual operators are routed via the automatic switches and a common group of junctions to the manual exchange. Generally speaking, dialling-out routes are intended to cater only for terminal traffic to the objective manual exchange or its dependants. The circuit arrangements make provision for automatic registration of the call when the called subscriber on the manual exchange replies. If the objective manual exchange is outside the unit-fee radius 2-, 3-, or 4-unit fees may be recorded, depending upon the radial distance of the call. Dialling-out routes can be, and often are, provided to exchanges outside the range of the multimetering equipment at the automatic exchange. In such circumstances it is necessary to ticket the call at the incoming manual centre. Dialling-out routes to the automanual switchboards of adjacent automatic networks are provided only in exceptional circumstances, and no circuits have been developed to provide automatic metering on such calls.

Service considerations make it inadvisable for coin-box subscribers to be given access to dialling-out routes. The standard coin-box circuit of an automatic system is designed so that the subscriber must press button A (and thereby deposit the coins in the cash box) before he can speak to the called party. It would therefore be necessary for a coin-box user to press button A before he could pass a request to a distant manual exchange operator. If the call is ineffective, then difficulties arise in arranging for a refundment to the caller. Apart from this, however, it is not desirable to give coin-box users access to dialled-out exchanges beyond unit-fee radius, since it would be necessary to withdraw these facilities when the distant exchanges are converted to automatic working.

Supervision and Metering. The provision of a dialling-out route to a manual exchange introduces some interesting signalling problems. Possibly the most important of these is the co-ordination of manual supervisory conditions with the automatic metering facilities which are required on calls from subscribers. Fig. 501 shows a simple trunking scheme in which automatic subscribers on exchange *B* are given access via level 64 to the operator at a nearby manual exchange *C*. A further manual exchange *A* must also be given access to exchange *C* via the automatic switches at the intermediate exchange *B*.

The standard system of signalling over manual junctions is battery on the − (or *B*) wire to call, and the return of battery over the + (or *A*) wire as a supervisory signal. The supervisory or answering signal can be used at the originating exchange *either* to darken the supervisory lamp at a manual switchboard, *or* to initiate the metering cycle if the call originates from an automatic subscriber. The same signal is used for both purposes. In the same way, if loop calling is adopted, the normal supervisory signal is a reversal of the line current back to the originating exchange. This again can be used either to control the metering, or to darken the supervisory lamp if the call originates from a manual switchboard. The use of a common signal either to control a manual board supervisory lamp or to effect metering against an automatic subscriber introduces certain complications.

The normal B-position cord circuit at a manual exchange is arranged so that the supervisory signal is returned to the originating exchange when the B-position telephonist answers by throwing her speak key. After ascertaining the number required, the B-position operator extends the call to the required line in the outgoing multiple, and restores her speak key. This withdraws the answering condition from the junction, so that the supervisory lamp at the originating exchange now glows until such time as the answering signal is reconnected when the called subscriber replies. If, now, an incoming junction route carries traffic both from distant operators and from automatic subscribers, any attempt to provide "key supervision" would result in premature metering if the call originates from an automatic subscriber. There are three recognized methods of dealing with such traffic.

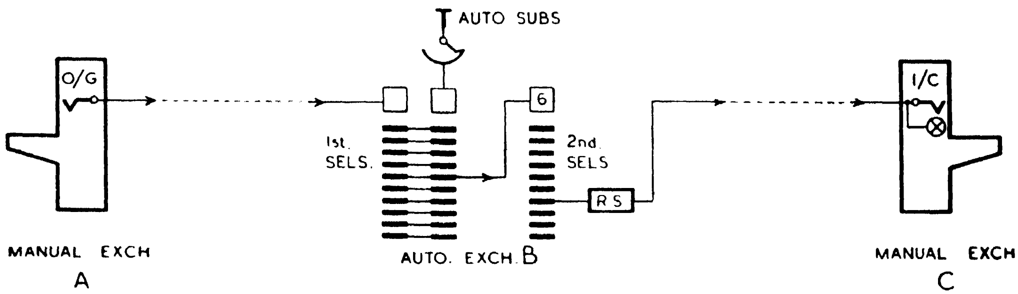


Fig. 501. Simple Trunking Scheme with Joint Use of Dialled-out Route

The first is to remove key supervision from all the cord circuits on positions which may be required to deal with dialled-out traffic from distant automatic subscribers. This course eliminates the danger of premature metering, but distant manual exchanges lose the normal supervisory signal when the incoming telephonist answers. It should be noted that key supervision on manual-to-manual calls is lost not only on the routes where there is joint access, but also on all other incoming routes to the B-position (or positions) concerned. It is possible to tolerate the loss of key supervision on a comparatively small number of calls from distant manual exchanges. If, on the other hand, the volume of traffic from automatic subscribers is small compared with the total traffic handled at the B-position, then the loss of key supervision facilities is more serious, and a more satisfactory method is desirable. In some cases "mixed" cord circuits are provided so that the operator can select the appropriate cords for use on calls incoming from manual exchanges over *direct* routes.

An alternative method is to retain the standard B-position cord circuit, but to modify the incoming junction terminations on routes which carry traffic both from subscribers and operators. The incoming junction termination on such routes can be arranged so that the supervisory signal returned from the speaking key (when the incoming call is answered) is intercepted in the line termination and is not transmitted back to the originating exchange. In due course, when the

called subscriber replies, the supervisory signal from the cord circuit is made to light a meter lamp in the junction termination, and, by depressing a special metering key associated with that lamp, the B-position operator can extend the supervisory signal back to the originating exchange. By the adoption of this arrangement, key supervision is retained on all purely manual-to-manual routes, and is lost only during the initial answering conditions on joint user routes. (Once the B-position operator has ascertained that the call is from a distant manual exchange, she can give key supervision from that time by depressing the meter key.) The disadvantage of this method is, of course, the necessity for a manual operation on the incoming B-position to establish the supervisory or metering condition. The meter lamp and the metering key per junction also take up an appreciable amount of panel space.

The third alternative is to arrange for manual ticketing of all dialled-out calls from subscribers. Although this puts a considerable additional load on the operator at the incoming exchange, it enables standard manual supervisory conditions to be returned—the equipment at the automatic exchange being arranged so that the supervisory signals are repeated back to any manual exchange, but on locally originated calls these signals are ineffective. This scheme may introduce difficulties if other automatic exchanges have access to the dialling-out route. In such cases the supervisory signals are transmitted back to the originating exchange, and would cause premature metering unless special arrangements are made to suppress the supervisory signals. (Certain types of multi-metering equipment can be arranged to give the correct metering fee when a distant automatic exchange is dialled, but to suppress metering if the code dialled relates to a distant manual exchange where arrangements are made for ticketing.)

Follow-on Calls. On dialled-out calls to a distant manual exchange the originating automatic subscriber normally controls the holding and release of the connexion (i.e. it is not usual to provide manual hold on dialling-out routes). At the termination of the call, the originating subscriber replaces his receiver, and within a fraction of a second the local automatic selectors restore to normal. The removal of the calling loop also gives a clearing signal to the manual exchange operator, but there may be a period of some seconds before the connexion is taken down at the manual exchange. There is therefore a danger that the outgoing junction from the automatic exchange may be seized for a second call before the first call has been cleared at the manual switchboard. It is important that this second call should not be lost, and also that the second caller should not be connected to the called party of the first connexion. The circuit arrangements on dialling-out routes must be specially designed to provide for the possibility of a second (or *follow-on*) call, and must ensure that any such calls are correctly routed.

One method, which has been used extensively, is to provide a special incoming circuit at the manual exchange. This circuit is designed so that, if a second call arrives before a previous call has been cleared by the telephonist, the calling lamp is re-lighted and the speaking pair is disconnected until such time as the answering plug is withdrawn from the incoming junction jack. As an alternative to this arrangement, the circuit can be arranged so that the automatic equipment at the originating exchange is held until the plug is withdrawn from the answering jack, i.e. manual hold facilities. It is then impossible for a second call to seize the outgoing junction to the manual exchange until the first call is completely cleared at the B-position. This is not a very desirable arrangement from the automatic subscriber's point of view (since it may prevent him from making a second call immediately after a call to the manual exchange).

An alternative and better arrangement is to design the circuit so that the automatic switching train is released when the calling subscriber replaces his receiver, but to arrange the circuits so that the outgoing junction is automatically engaged (after being released from the first call) until the answering plug is withdrawn from the incoming junction jack. There may be a short unguarded interval with this arrangement between the release of the local switching train and the re-establishment of the engaged condition on the outgoing junction, but this is unavoidable and does not normally introduce service difficulties.

Dialling-out to C.B. Exchanges. Fig. 502 shows a typical circuit at an automatic exchange suitable for use on a dialling-out route to a C.B. exchange. The junction termination at the latter is illustrated in Fig. 503, which also shows the main signalling features of the cord circuits on the B-position.

The circuits are designed for standard C.B. signalling over the junction. The B-position cord circuits are modified to delete key supervision so that the supervisory signal is returned to the automatic exchange only when the called subscriber replies. If a second call should seize the junction before the previous call has been disconnected at the B-position, the calling lamp is re-lighted and the junction is isolated from the cord circuit until such time as the answering plug is withdrawn from the junction jack.

Relay L (Fig. 502) operates to the loop extended from the previous selectors, and at **$L1$** operates relay B. **$B1$** applies a guarding earth to the P-wire, whilst **$B2$** operates relays BA and J. **$BA2$** extends battery via I to the — wire of the junction to operate relay L (Fig. 503) at the manual termination. **$L1$** operates relay B and **$B2$** in turn lights the calling lamp. Ringing tone is now returned to the calling party via contact **$B4$** and the + wire of the junction.

When the operator inserts a plug into the answering jack, the operation of relay S disconnects the calling lamp, whilst the earth returned over the tip conductor of the answering cord operates relay T. **$T1$** provides a local holding circuit for relay T under the control of relay B, whilst **$T2$** removes the earth from the — line and extends this wire through to the cord circuit. The calling subscriber now passes his instructions to the operator.

After testing the required line, the telephonist inserts the calling plug into the multiple jack. Relay S in the sleeve circuit of the calling cord now operates to the earth on the bush of the called subscriber's line circuit. When the called subscriber replies, relay LC operates to the forward loop, and at **$LC1$** extends battery via **$S1$**, the ring conductor of the answering cord, and the + wire of the junction to operate relay D (Fig. 502) in the outgoing relay set at the automatic exchange.

Contact **$D1$** now operates the relief relay DA, and **$DA2$** and **$DA3$** reverse the current in the incoming loop for supervisory purposes. (This is required when the call originates from a manual exchange.) **$DA1$** operates relay DD, and **$DD1$** applies + battery metering conditions to the P-wire. **$DD3$** disconnects the circuit for relay J and at the end of a slow release period the restoration of $J1$ removes the metering potential from the P-wire.

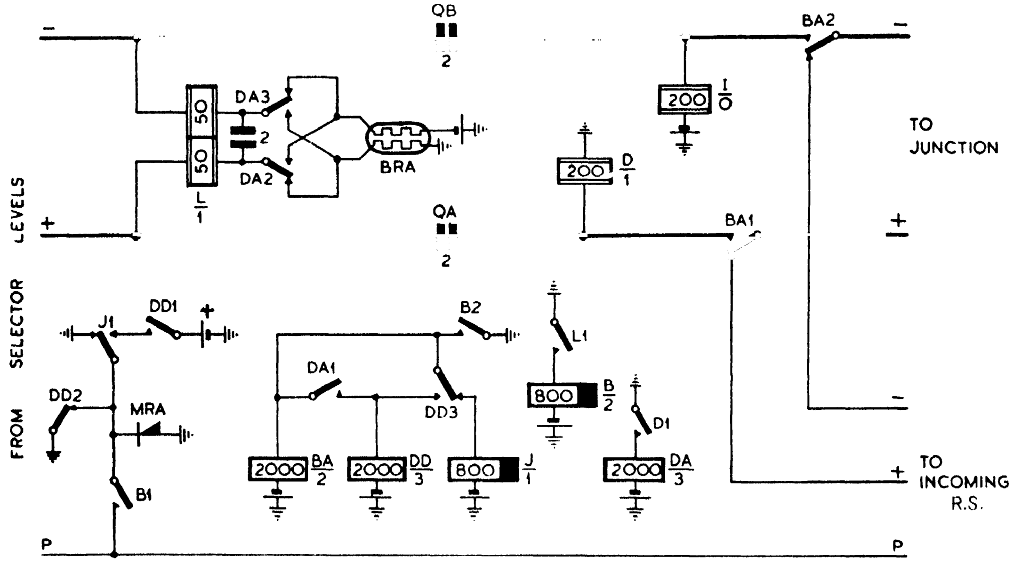


FIG. 502. OUTGOING CIRCUIT TO C.B. EXCHANGE

At the end of the call relays L, B, BA, and DD at the automatic exchange restore to normal. The restoration of $BA2$ removes the holding condition from the — wire of the junction and releases relay L (Fig. 503) at the manual exchange. L releases B, and the restoration of $B1$ completes a circuit for relay CO to the earth at **$S4$**. **$CO1$** and **$CO2$** disconnect the junction from the cord circuit. The release of $B3$ disconnects relay T so that a re-operate circuit for L is provided at contact $T2$. The withdrawal of the calling condition allows relay LA in the cord circuit to release, and a circuit is provided for the answering cord supervisory lamp at $LA1$.

If a second call should seize the junction before the operator clears down the connexion from the first call, the calling condition re-operates relay L, and **$L1$** operates B (Fig. 503). **$B1$** now completes a circuit for the calling lamp from the earth at **$S4$** via **$CO3$**, **$B1$**, and **$S1$**. **$B4$** returns ringing tone to the caller. The re-lighting of the calling lamp draws the attention of the operator to the follow-on call, and the removal of the answering plug from the junction jack releases relay S. $S4$ in turn

releases CO, and $CO4$ disconnects the ringing tone. The operator now answers the call in the usual way, and the circuit sequence is as already described.

Fig. 504 shows the modifications necessary on the incoming junction circuit if the cord circuits call, the arrangements at a C.B.S. or magneto exchange do not provide such facilities. Instead, the relay set at the automatic exchange is arranged to busy the outgoing junction at the termination of a call until such time as the plug is withdrawn from the answering jack at the manual exchange.

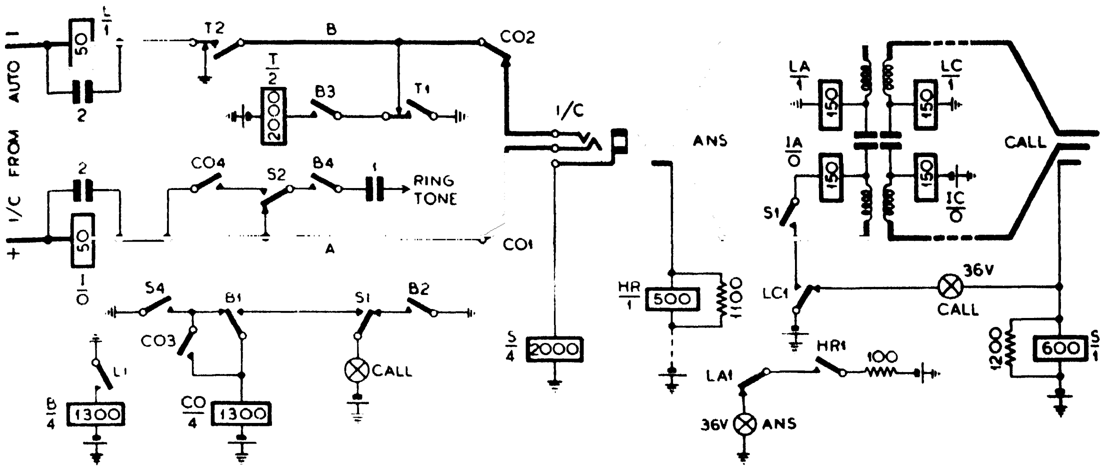


FIG. 503. INCOMING JUNCTION FROM AUTO WITH CORD CIRCUITS MODIFIED TO REMOVE KEY SUPERVISION (C.B. EXCHANGE)

on the B-position are arranged to give key supervision. The modifications require two additional relays M and D, and a meter lamp which is controlled by relay D. The + line of the junction is normally dissociated from the ring conductor of the cord circuit by contact $M2$. When the operator answers a call and throws her speak key, supervisory battery is returned via the auxiliary speak key contacts and the ring conductor of the answering cord to operate relay D. **$D1$** lights the meter lamp, but the operator ignores the lamp signal at this stage of the call. In due course the connexion is extended to the required subscriber, and when the latter replies relay D again operates. On seeing this signal, the B-position operator depresses the non-locking meter key associated with the incoming junction. This energizes relay M which locks via its own contact (**$M1$**) for the duration of the call. **$M2$** now extends the supervisory battery to the + wire of the junction to initiate metering at the automatic exchange.

Dialling-out to C.B.S. and Magneto Exchanges. Fig. 505 shows the circuit arrangements of the relay set used on outgoing routes to C.B.S. and magneto exchanges, whilst Fig. 506 gives the incoming termination at an exchange of the C.B.S.2 type.

Whereas the C.B. exchange termination (Fig. 503) provides for the acceptance of a follow-on When the caller is extended to the outgoing relay set, relay L (Fig. 505) operates to the loop and **$L1$** operates relay B. **$B1$** guards the circuit against intrusion, whilst **$B3$** operates relay HJ. **$HJ2$**

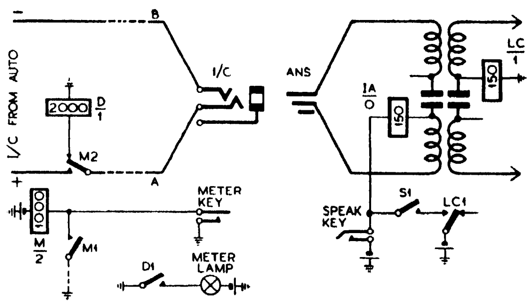


FIG. 504. ALTERNATIVE ARRANGEMENTS OF INCOMING JUNCTION FROM AUTO WHEN IT IS DESIRED TO RETAIN KEY SUPERVISION ON B-POSITION CORD CIRCUITS

returns ringing tone to the caller. **$HJ4$** transmits battery via the 200 Ω resistor YA over the − line of the junction to operate the calling indicator at the C.B.S. exchange.

In due course the operator answers the call and relay J of the cord circuit (Fig. 506) operates to the earth on the bush of the answering jack. Earth is now transmitted via **$J2$**, $C1$, the ring conductor

of the cord circuit, and the + line of the junction to operate relay *BD* in the outgoing relay set (Fig. 505). ***BD*2** disconnects the holding circuit for *HJ* and at the same time provides a local *J*2. This earth is extended over the + wire of the junction and contact ***HJ*3** to hold relay *BD*. So long as this condition persists, *HJ* is held from the earth at *B*3 via ***BD*3**, and the guarding con-

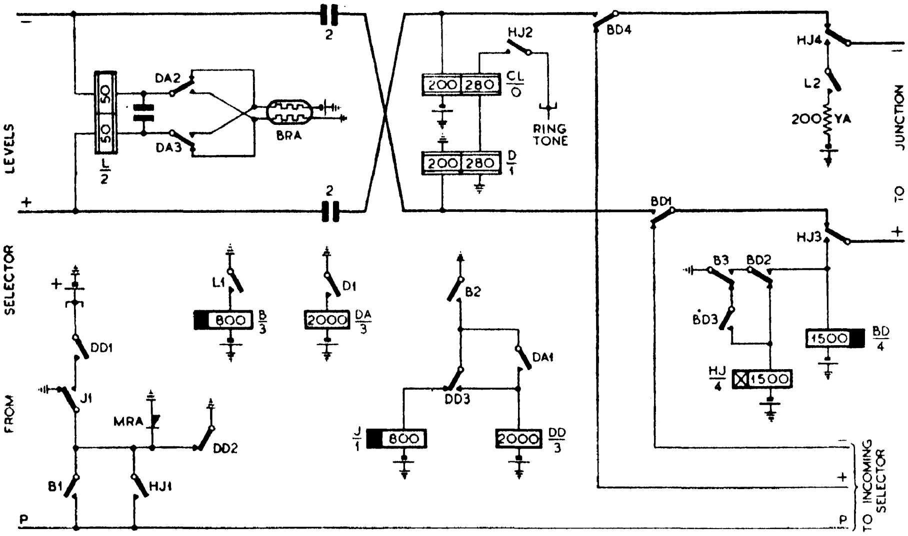


FIG. 505. OUTGOING RELAY SET AT AUTOMATIC EXCHANGE ON JUNCTIONS TO C.B.S. OR MAGNETO EXCHANGES

circuit for the *BD* relay. ***BD*1** and ***BD*4** prepare the speaking circuit. After a short delay period, *HJ* releases and at *HJ*3 and *HJ*4 completes the transmission path. *HJ*2 disconnects the ringing tone.

The request is now passed to the B-position operator at the distant exchange, and the call is extended to the required subscriber. In due course the called party replies, and the loop operates relay *LC* (Fig. 506). ***LC*1** now operates relay *C*, and ***C*1** disconnects the earth from the + line and replaces it by a battery potential. Relay *D* in the outgoing relay set (Fig. 505) now operates and at ***D*1** energizes relay *DA*. Contacts ***DA*2** and ***DA*3** repeat the supervisory condition, whilst ***DA*1** completes the circuit for relay *DD*. The operation of ***DD*3** disconnects the holding circuit of relay *J* (which was operated on the closure of contact ***B*2**). A + battery metering signal is thus returned to the calling subscriber during the release lag of relay *J* (i.e. during the period when contacts ***J*1** and ***DD*1** are both closed).

At the end of the call the release of relay *L* allows relay *B* to release, and the restoration of contact *B*3 provides a re-operate circuit for *HJ*. ***HJ*1** now re-applies a guarding earth to the *P*-wire. At the manual exchange the called subscriber replaces his receiver at the end of the call, and the supervisory battery is replaced by the earth via dition is maintained on the *P*-wire of the selector banks. When the call is cleared at the manual exchange, the removal of the answering plug from the incoming jack disconnects the current in the + wire, thereby allowing relays *BD* and *HJ* to restore in sequence. The final restoration of *HJ*1 removes the guarding condition and makes the circuit available for use on another call.

Conditions may occasionally arise where the called subscriber remains on the line when the caller has replaced his receiver. In such circumstances relays *LC* and *C* of the cord circuit remain operated, and the battery is maintained on the + wire of the junction to the automatic exchange. In these circumstances, the difference in voltage of the C.B.S. and the automatic exchange batteries allows sufficient current to flow to hold relay *BD*.

Calls to Sleeve Control Manual Board in Same Building as Automatic Equipment. With very few exceptions all automanual switchboards are of the sleeve control type. There are various groups of circuits from the group selector levels of the automatic equipment to the automanual switchboard to cater for "0 level" traffic, assistance calls, enquiries, and so on. In most cases metering is not required, but it is usual to provide *manual hold* facilities. If the automanual switchboard is

in the same building as the automatic equipment, manual hold can readily be provided by extending the P-wire to the sleeve control line termination and by arranging for earth to be applied to this wire for so long as the plug remains in the answering

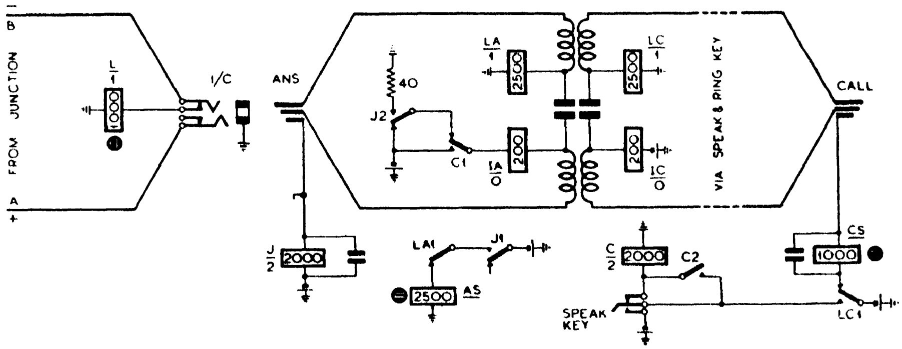


FIG. 506. INCOMING JUNCTION (AND PART OF CORD CIRCUIT) AT C.B.S.2 EXCHANGE FOR CIRCUITS INCOMING FROM AUTO

jack. With these circuit arrangements there is no follow-on call problem.

Fig. 507 shows a typical trunk demand or

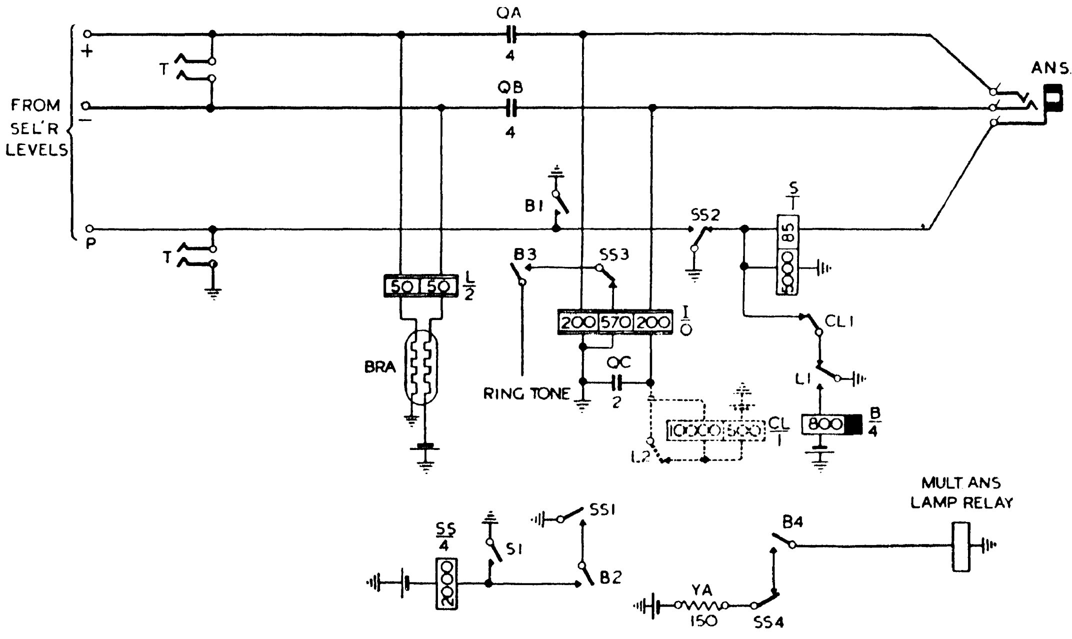


FIG. 507. TRUNK DEMAND OR ASSISTANCE CIRCUIT (SLEEVE CONTROL AUTOMANUAL BOARD IN SAME BUILDING AS AUTOMATIC EQUIPMENT)

assistance circuit suitable for use at a sleeve control manual board which is located in the same building as the automatic plant. The arrangements follow the standard sleeve control practice. Relay L operates to the loop extended from the group selector, and at **L1** operates relay B. **B4** energizes the multiple answering lamp relay. When the operator inserts an answering plug into the jack, relay S operates and at **S1** energizes the relief relay SS. **SS3** now applies a holding and guarding earth to the P-wire for so long as the plug remains in the jack even if relays L and B are released by the calling subscriber.

Circuits to Remote Sleeve Control Automanual Board. If the automanual board is located in a separate building from the automatic equipment, it is not practicable to extend the P-wire between the two points. In these circumstances somewhat

different arrangements are necessary to provide the manual hold facility over the basic speaking pair. Fig. 508 shows a circuit suitable for use on an outgoing junction to a remote sleeve control manual board where manual hold, but no metering, is required. The associated manual board termination is given in Fig. 509. The calling condition is the normal battery extended over the — wire of the junction to operate relay L at the automanual exchange. The relief relay LL lights the multiple answering lamps. When the operator answers the call, the operation of relays S and SS extinguishes the lamp and returns battery over

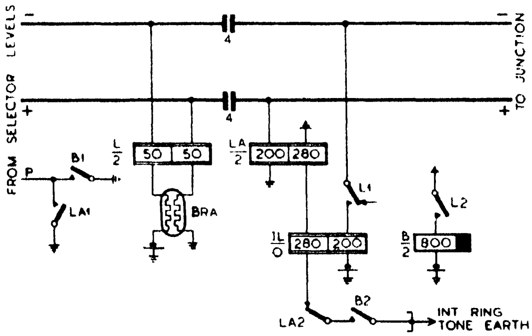


FIG. 508. TRUNK DEMAND OR ASSISTANCE CIRCUIT TO REMOTE AUTOMANUAL SWITCHBOARD

the + wire of the junction to operate relay LA in the outgoing relay set at the automatic exchange. Contact $LA2$ disconnects the ringing tone applied on the seizure of the circuit by contact $B2$. If the calling subscriber clears whilst the plug remains in the answering jack, an earth is maintained on the P-wire by contact $LA1$, thereby providing manual hold under the control of relay S at the automanual exchange.

The principle of manual hold utilized in Figs. 508 and 509 cannot be applied under circumstances when the circuit at the automatic exchange is required to carry both auto and manual traffic. The conditions in a director exchange provide a typical example. In this case the supervisory relays, etc., are included in the 1st code selector which may be required to carry traffic to automatic subscribers (via numerical selectors and a final selector) or, alternatively, traffic to a sleeve control automanual board. If the 1st code selector circuit were arranged to give manual hold on receipt of battery returned over the + wire (as in Fig. 508) the manual hold condition would be imitated on calls to a local automatic subscriber when the connexions of the final selector A relay are reversed to give normal supervisory conditions. This would result in called party release, which is not permissible. Similar conditions also exist on some discriminating selector circuits used at satellite exchanges in a non-director area.

Figs. 510 and 511 show the somewhat more complex arrangements which are necessary to provide manual hold in these circumstances. The principle has already been considered in Chapter IX.

The operation of relay L in the selector circuit at the automatic exchange completes the loop forward to energize relay L in the manual board termination. Relay L now lights the calling

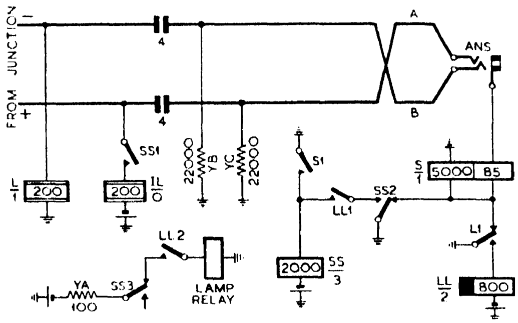


FIG. 509. TERMINATION AT AUTOMANUAL SWITCHBOARD OF TRUNK DEMAND OR ASSISTANCE CIRCUIT FROM REMOTE AUTOMATIC EXCHANGE

lamp via the slugged relief relay B. The insertion of an answering plug into the line jack operates relay S, which in turn operates relay SS, and contacts of the latter extinguish the calling lamps. If the calling subscriber clears whilst the plug is still in the jack, relay OH operates on the release of contact $L1$ to the earth at $S2$. $OH3$ now disconnects the L relay from the + line, and applies battery via the 200 Ω resistor YB. This battery is extended via relay I (Fig. 510) and contact $L2$ to operate relay MH in the automatic equipment. $MH1$ now provides a holding circuit for relay B, thereby maintaining the earth on the P-wire to prevent release of the connexion. This condition is maintained until the operator withdraws the plug from the jack. If the subscriber should recall during the manual hold period, the re-operation of contact $L2$ re-establishes the loop to the manual exchange, thereby operating relay MH (Fig. 511). $MH1$ re-energizes the line relay L over a local circuit. $L1$ re-operates relay B and disconnects relay OH. The release of $OH1$ darkens the answering supervisory lamp of the cord circuit. Contacts $MH2$ and $B2$ provide for the holding of relay MH until such time as relay B is fully operated.

Parent Exchange Calls from U.A.X.s. Normally the junctions from a U.A.X. to its parent exchange carry both "9" level calls (to the parent automatic equipment) and "0" level calls to the parent exchange manual board. The necessary discrimination is obtained by using single-wire signalling for calls to the manual board, and loop signalling for the U.A.X.-to-auto calls. Further discrimination is required on manual board calls to distinguish between calls from ordinary and coin-box users. The discrimination arrangements at the U.A.X. have already been described in Chapters XIV, XV, and XVI.

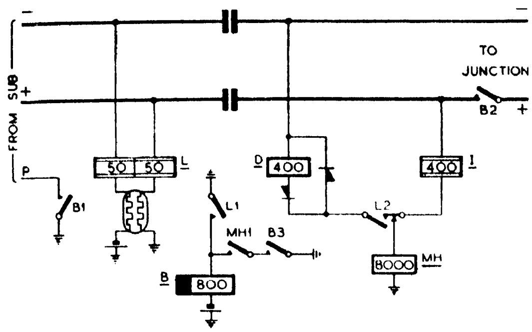


FIG. 510. PART OF 1ST CODE SELECTOR CIRCUIT (DIRECTOR EXCHANGE) SHOWING SIGNALLING ARRANGEMENTS ON CALLS TO AUTOMANUAL SWITCHBOARD

The main features of the incoming circuit at a parent exchange of the sleeve control type are shown in Fig. 512. The circuit operation under the various conditions of use is as follows:

"0" *Level Call from Ordinary Subscriber*. When an "0" level call originates from an ordinary subscriber, signals are transmitted over the junction in the following sequence:

(*a*) When the junction is seized at the U.A.X., battery is forwarded to the parent exchange over the *A*-wire (+ wire). This causes the "ordinary" calling lamp to glow.

(*b*) When the operator plugs in, the + wire is disconnected at the parent exchange, and the disconnexion of this line now causes the U.A.X. junction equipment to forward an earth to the parent exchange over the *B*-wire (— wire).

(*c*) The receipt of the earth on the — wire at the parent exchange restores the + wire circuit.

(*d*) When the operator throws her speak key (or, later, when the called party answers) battery is returned from the parent exchange on the — wire.

The initial calling signal (battery on + wire) operates relay *LA* at the parent exchange termination, and ***LA*1** in turn energizes *B*. A circuit is now completed at ***B*2** for the lamp relay associated with the "ordinary" calling equipment. When the operator inserts an answering plug, relay *S* operates from the battery on the sleeve of the answering cord, and ***S*1** operates *SC*. ***SC*1** completes a circuit for *SS*, ***SS*2** prevents the seizure of the incoming selector, whilst ***SS*4** disconnects the *LA* relay. Relay *B* is now held via ***SC*2**, whilst the calling lamp relay is released at ***SS*5**. The disconnexion of the + wire at ***SS*4** causes the outgoing relay set at the U.A.X. to apply an earth to the — wire. At the parent termination this earth

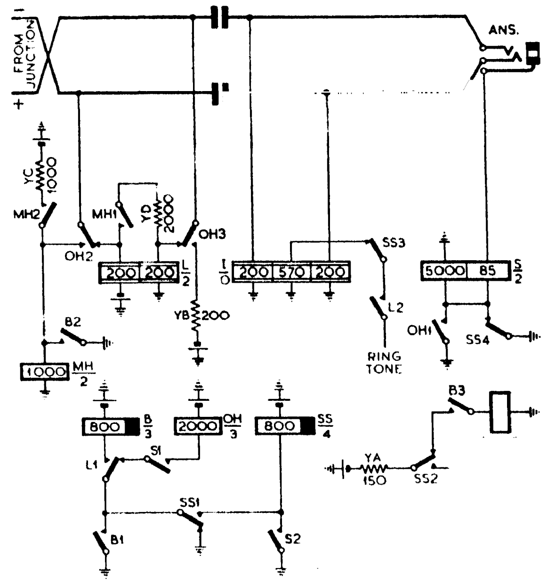


FIG. 511. TERMINATION AT SLEEVE CONTROL MANUAL BOARD OF TRUNK DEMAND CIRCUIT FROM REMOTE DIRECTOR EXCHANGE

signal operates relay *CH* via ***SS*3**, ***B*5**, *CB*4, and *CH*1. Relay *CH* locks to its own contact (***CH*3**) and at ***CH*5** re-applies the *LA* relay to the + line, thereby indicating to the U.A.X. that the + wire has been restored. *LA* now re-operates and, at ***LA*1**, provides a retaining circuit for relay *B*.

The operation of the cord circuit speak key allows relay *DR* to operate due to the unbalanced currents in its two windings. (This is a common arrangement in sleeve control circuits—see Vol. I.) ***DR*1** operates *DA*, and ***DA*1** returns the battery at *LB* over the — wire to the U.A.X. This is the answering signal and is primarily required to darken the supervisory lamp at distant exchanges which obtain calls to the parent exchange via the U.A.X. equipment. When the speak key

is restored, the answering signal is withdrawn, but the condition is re-established when the called party replies. In the latter case, *DA* is controlled from the battery condition over the ring conductor of the cord circuit. Manual hold is provided by returning battery over the + wire to the U.A.X. for so long as the plug remains in the answering jack. The principle is the same as that shown in Figs. 510 and 511, and the circuit details have been omitted from Fig. 512 to avoid confusion.

"0" *Level Call from Coin-box Subscriber.* When the call originates from a coin-box user, the signals

Relay *LB* operates to the calling earth on the – wire, and at ***LB*1** operates *CB*. ***CB*2** completes a circuit for relay *B*, whilst contacts ***B*2** and ***CB*3** complete the circuit for the C.C.B. answering lamp relay.

When the operator answers, relay *S* operates, and *SC* and *SS* are operated in sequence as before. The circuit for relay *LB* is now disconnected at ***SS*3**, but an alternative holding circuit for relay *B* has now been provided at ***SC*2**. Relay *CB* is held at this stage to the earth at its own contact ***CB*1**. The operation of ***SS*5** releases the lamp relay.

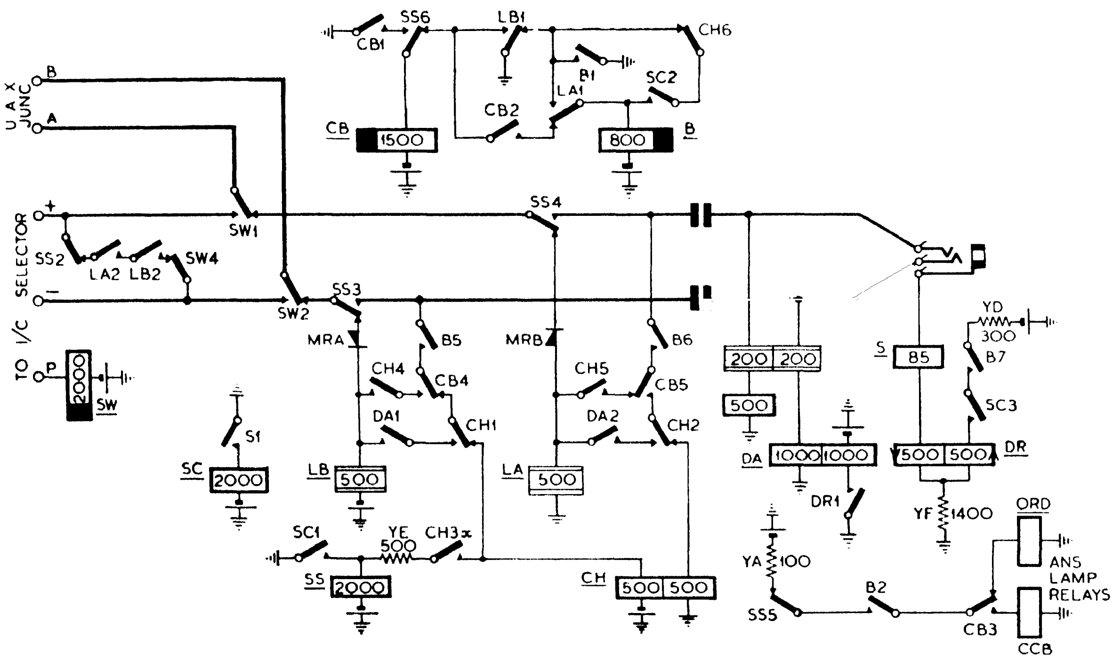


FIG. 512. TERMINATION OF U.A.X. JUNCTIONS AT PARENT AUTO-MANUAL SWITCHBOARD (SLEEVE CONTROL)

between the U.A.X. and the parent exchange are as follows:

(*a*) When the junction is seized at the U.A.X., earth is forwarded to the parent exchange over the – wire. This causes the C.C.B. calling lamp to glow.

(*b*) When the operator plugs in, the – wire is disconnected at the parent exchange, and the disconnexion of this line causes the U.A.X. junction equipment to forward a battery to the parent exchange over the + wire.

(*c*) The receipt of the battery on the + wire at the parent exchange restores the – wire circuit.

(*d*) When the operator throws her speak key (or, later, when the called party replies) earth is returned from the parent exchange on the + wire.

The disconnexion of the – wire (at ***SS*3**) causes the U.A.X. equipment to forward a battery on the + wire. On receipt of this second incoming signal at the parent exchange, relay *CH* operates via ***SS*4**, ***B*6**, ***CB*5**, and *CH*2. The *CH* relay locks to the ***CH*3** contact, whilst ***CH*4** reconnects the *LB* relay to the – line. *LB* now re-operates and, at ***LB*1**, takes over the holding circuit of the *B* relay.

When the operator throws her speak key, *DR* operates to the unbalanced conditions and, in turn, operates *DA*. ***DA*2** now provides the answering supervisory signal (earth on + wire).

"9" *Level Calls.* On calls to the automatic equipment at the parent exchange centre, a *loop* signal is forwarded from the U.A.X. Relays *LA* and *LB*

both operate in series with the loop, and contacts *LA2* and *LB2* complete a circuit for the seizure of the incoming selector. Relay *SW*, which is connected to the *P*-wire, operates to the earth returned from the selector and, at *SW1* and *SW2*, switches the calling loop to the incoming selector. Contact *SW4* opens the temporary loop applied at *LA2* and *LB2*, the selector now being held from the junction loop. The impulses from the calling subscriber are repeated over the junction to step the switching train at the parent exchange in the usual way.

Auto-Manual Traffic in Large City Areas. The automatization of the telephone network in a large city provides some special problems in the handling of the traffic between automatic and manual subscribers during the transition period. We have already seen that in a heavily telephoned city area a large proportion of the traffic is routed over junctions to adjacent exchanges. Hence, during the initial stages of the automatization programme a high percentage of the traffic from automatic subscribers is to the subscribers on nearby exchanges of the manual type. It is generally uneconomical to route such traffic via the auto-manual switchboard. Even if suitable arrangements could be made, the service to the subscriber would undoubtedly suffer. The only alternative is to provide dialling-out routes from the automatic exchange selector levels to the adjacent manual exchanges.

The automatic system specially designed for use in large city areas employs a 3-digit exchange code followed by the 4 figures of the subscriber's number (see Chapter XIII). This permits the use of 3-letter codes for obtaining access to a dialling-out route to a manual exchange. The 3 letters are, of course, the first 3 letters of the manual exchange name, and these are translated in the director to the necessary routing digits to establish the call via code selector levels at the automatic exchange. (The translation facility also permits routing via one or more tandem centres if this is desirable.)

The use of 3-letter dialling codes to obtain access to the manual exchanges in a director area has one major disadvantage which may become a serious problem during the early stages of conversion in a very large city such as London. The telephone subscribers do not know which of the exchanges in the area are manual and which are automatic. It is therefore necessary to give instructions in the telephone directory for the subscriber to dial the 3 initial letters of the exchange followed by the 4-figure subscriber's number on calls to automatic subscribers, and also to advise him to dial the 3 initial letters (without the number) if the required subscriber is connected to a manual exchange. (It would be unsatisfactory to expect a subscriber to dial the full 7 digits in all cases only to be requested by the incoming B-position operator at the manual exchange for a repetition of the number required.)

The different dialling instructions for calls to manual and to automatic subscribers require the issue of a new telephone directory each time an exchange is converted to automatic working. Where there are a very large number of exchanges, as in London, it is necessary to convert exchanges at fairly frequent intervals in order to complete the automatization programme within a reasonable period. The problem of issuing a large and expensive directory for each conversion then becomes a matter of some importance. Moreover the instructions to the subscriber are in a continual state of flux, and difficulties are liable to occur due to the frequent changes of dialling instructions.

The difficulties can be overcome by the provision of equipment at the manual exchanges which will record the numerical digits dialled by automatic subscribers and utilize these digits to give a visual display to the B-position operator. If such equipment is available, all subscribers in the area can be instructed to dial the 3 initial letters of the exchange name followed by the 4 digits of the subscriber's number on *all* calls, irrespective of whether they are to subscribers on automatic or on manual exchanges. Individual manual exchanges can then be converted to automatic working without regard to directory issues.

The method is known as *call indicator working* and has been in use for some years in the London and Manchester areas. The provision of call indicator equipment at all manual exchanges in a city area involves a considerable cost. A large amount of equipment is required during the early stages of the automatization programme, but the plant rapidly becomes surplus as one exchange after another is converted to automatic working. Hence, in addition to its high cost, the call indicator equipment has also a comparatively short life.

The only practicable alternative to the use of call indicator equipment is to arrange for the conversion of the area in carefully planned stages, each stage being co-ordinated with the issue of a new directory. In the cities outside London it is quite practicable to arrange for the exchanges to be converted to automatic working in groups of, say, six exchanges at intervals of twelve months or so. This method has been used in the Liverpool, Birmingham, Glasgow, and Edinburgh Areas and

has proved to be quite satisfactory. The disadvantage of the method does, of course, lie in the necessity for very close co-ordination between the various works in order to permit of the conversion of a number of exchanges at one time. This must be weighed against the high cost of providing call indicator equipment.

Call Indicator Working. The design of the call indicator equipment at a manual exchange is largely influenced by the following considerations:

(*a*) In view of the fact that it is required only for a limited period and may then have to be scrapped, the initial cost should be low.

(*b*) The space required for the equipment must be as small as possible since it is to be installed in existing exchanges, many of which are already filled to capacity with manual equipment.

(*c*) The power consumption must be low in order that it can work from the existing manual exchange batteries without the need for a complete replacement of the manual exchange power plant.

(*d*) The equipment should be capable of installation without interfering with the service at the existing manual exchange. (The call indicator equipment must, of course, be fitted whilst the manual exchange is working at full load.)

One method of providing call indicator facilities would be to transmit loop-disconnect impulse trains over the junction to the manual exchange, and to provide impulse counting and impulse storage circuits in each incoming junction termination. Facilities could then be provided to transfer the stored digits to a lamp display as soon as a B-position became free to accept a call. The provision at the manual exchange of impulse counting and storage circuits on the basis of one per junction is somewhat costly and involves a considerable quantity of equipment. The impulse counting and storage circuits are, moreover, required only for a short period during the setting up of a call, and it is wasteful to provide these more or less complex circuits on the basis of one per junction.

It is preferable to locate the impulse counting and storage circuits in common equipment at the manual exchange which can be taken into use as required by any incoming junction. The number of such common circuits required depends partly upon the volume and incidence of the incoming traffic, and partly upon the speed at which the B-position operators complete the calls. The flow of telephone traffic is by no means smooth, and in practice a large number of calls may arrive in rapid succession at one point in the busy hour and this may be followed by a short period of very low traffic. During the periods of heavy traffic, calls may be held up in the storage equipment for an appreciable time before B-position operators become available to deal with them. A considerable number of counting and storage groups would therefore be necessary to ensure that a free circuit is *always* available whenever a call arrives. (Theoretically it would be necessary to provide one storage group per incoming junction to *guarantee* that a storage group is available for every incoming call, but the probability of such a large number of calls in rapid succession is extremely small and a reasonable grade of service could be given by providing a smaller number of storage units.)

The impulse trains used for routing a call in a director area are generated and transmitted by the director circuit. Considerable economies in the number of impulse counting and storage circuits required at a manual exchange can be obtained if facilities are provided to hold up the transmission of the numerical digits from the director until such time as storage equipment becomes available at the manual exchange. With such a scheme the rate of flow of traffic to the storage groups is no longer pure chance but can be controlled by the availability of free storage equipment. Whilst this principle is very attractive from the point of view of minimizing the equipment at the manual exchange, it does, of course, increase the holding time of the directors at the automatic exchanges, and this in turn necessitates more directors to carry the same volume of traffic (especially during the early stages of conversion when a large percentage of the calls are to manual switchboards).

The director contains a considerable quantity of apparatus which is not directly associated with the transmission of the numerical digits, and it is undesirable to prolong the holding time of these expensive units. On the other hand, it may be preferable to provide additional equipment at the automatic exchanges, if by so doing it is possible to reduce the amount of plant at the congested manual centres. Economy in the number of directors and in the quantity of equipment at the manual exchanges can both be obtained by providing a circuit at the automatic exchange which will receive the numerical digits from the director and store them until such time as the equipment at the manual exchange is available. The impulse storage equipment at the automatic exchange can be considerably simpler than the director circuit, and, by minimizing the holding time of the latter, the scheme produces an overall increase of efficiency.

It is interesting to examine the holding times of the storage equipment at the automatic exchange and of the storage equipment at the manual

exchange under the above conditions. At the automatic exchange the holding time of the storage equipment is made up of:

(*a*) The time taken to transmit and receive 4 impulse trains from the director.

(*b*) The waiting time before the equipment at the manual exchange is ready to receive the call.

(*c*) The time necessary to re-transmit the 4 numerical digits over the junction to the manual exchange.

Similarly, the impulse counting and storage equipment at the manual exchange is held for a period which is made up of:

(*a*) The time taken to transmit the 4 numerical digits from the automatic exchange.

(*b*) The waiting time before a B-position is available.

Both these holding times are materially shorter than the normal conversational time of a telephone call, and in each case the time taken to transmit the digits over the junction represents an appreciable proportion of the total holding time. If means can be found of transmitting the digits from the storage equipment at the automatic exchange to the storage equipment at the manual exchange more rapidly than by means of loop-disconnect impulsing, then the reduced holding time of the equipment will enable a smaller number of circuits to suffice with the consequent increase in efficiency. The impulse trains transmitted over the junction are not used to step automatic switch mechanisms, and there is no need to retain loop-disconnect impulsing if any alternative method is advantageous. It is readily possible to design a scheme of current pulses over the junction circuit which would enable a 4-digit number to be transmitted in a fraction of the time taken for the usual Strowger impulses. The digit counting circuit at the manual exchange must, of course, be specially designed to suit the system of coded pulses over the junction circuit. The method is known as the *coded call indicator system*.

Coded Pulse Signalling. Fig. 513 shows the method employed in the British call indicator system for transmitting numerical digits over a junction circuit to a manual exchange with call indicator facilities. There are three basic line signals, viz.:

Light Positive (*LP*)

Earth on positive wire.
Negative battery via 5000 Ω on negative wire.

Light Negative (*LN*)

Negative battery via 5000 Ω on positive wire.
Earth on negative wire.

Heavy Negative (*HN*)

Full negative battery on positive wire.
Full earth on negative wire.

These three fundamental signals can be used to indicate a large number of different conditions by varying the order in which they are transmitted over the junction. Thus: By using all three signals, the following permutations are available:

LP	***LN***	***HN***	*LN*	*HN*	***LP***
LN	***LP***	***LP***	*HN*	*LN*	***HN***
HN	***HN***	***LN***	*LP*	*LP*	***LN***

By using each signal more than once, the following additional permutations are obtainable from three consecutive signals:

LP	***LN***	*LN*	***LP***	***HN***	*HN*	*LN*	***HN***	*HN*	*LP*	*LN*	*HN*
LN	***LP***	*LN*	***HN***	***LP***	*HN*	*HN*	***LN***	*HN*	*LP*	*LN*	*HN*
LN	***LN***	*LP*	***HN***	***HN***	*LP*	*HN*	***HN***	*LN*	*LP*	*LN*	*HN*

By using single- and two-unit codes, the number of permutations can be still further increased as follows:

LP	*LN*	*HN*	*LP*	***LN***	***HN***	*LP*	*LN*	*LP*	*HN*	***LN***	***HN***
			LP	***LN***	***HN***	*LN*	*LP*	*HN*	*LP*	***HN***	***LN***

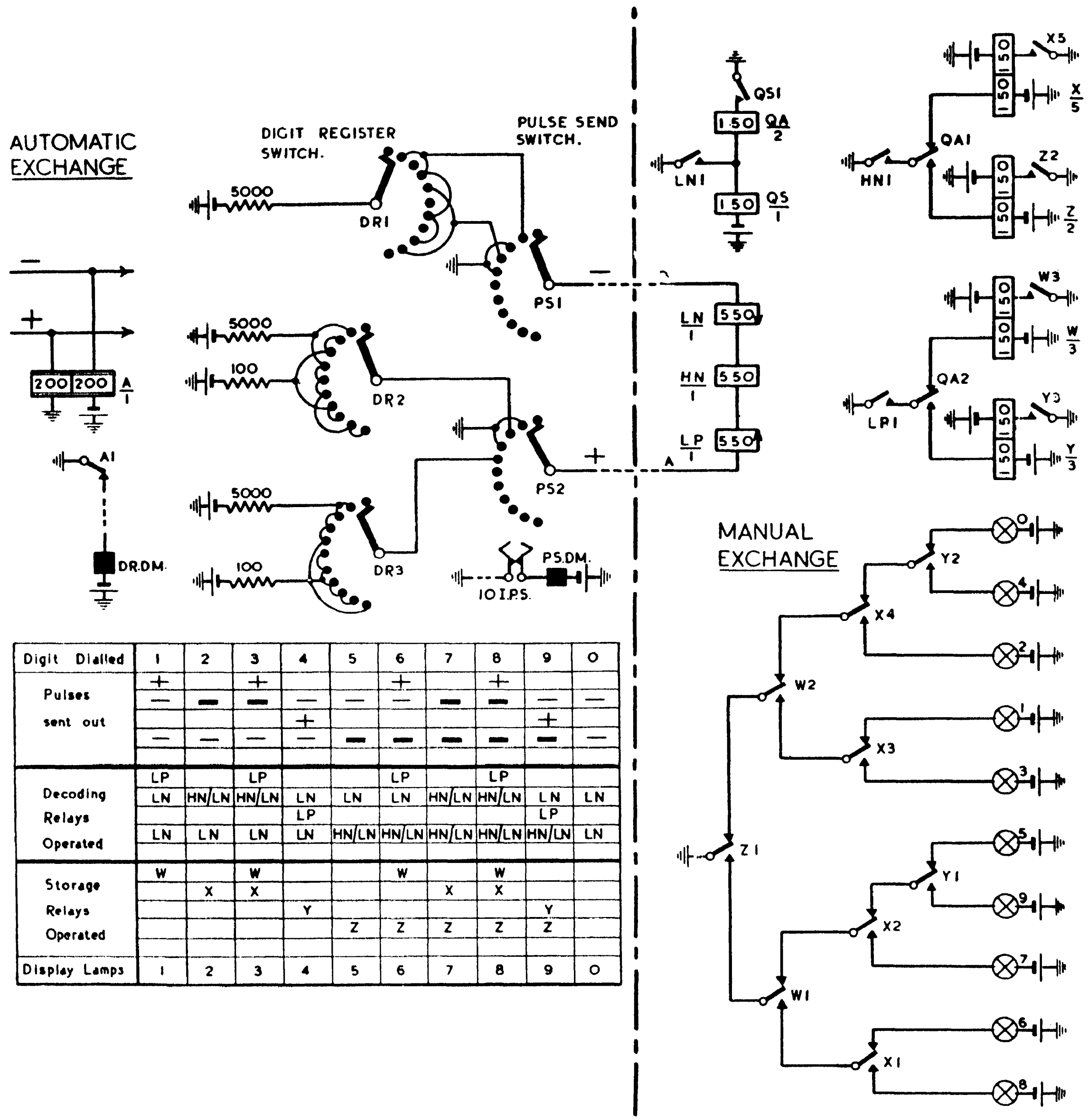
The incoming equipment at the manual exchange is required to determine when the signals for one digit have been completely received so that it can switch the receiving relays to the storage group of the next digit. This can be obtained by using combinations which consist only of, say, 3 pulses and by providing a counting circuit at the manual exchange so that, after receipt of the 3rd pulse, the receiving relays are switched to the next storage group. An alternative method is to select the codes so that the second application of a particular pulse signifies the end of the digit. This permits of a mixture of 2- or 3-unit codes, and is the method adopted in practice on account of the simplicity of the switching arrangements at the manual exchange.

The circuit is arranged so that switching from one storage group to another takes place after receipt of the second — pulse (either heavy or light). This restricts the number of codes available to those shown in heavy type above, but there are more than enough alternative arrangements to provide 10 distinctive signals for the digits 1 to 0.

The Strowger impulse trains received from the director are used to step a digit register uniselector (Fig. 513). There are 4 such uniselectors (one for each digit), and switching from one uniselector to

another is effected in the usual manner by the release of the C relay at the end of each impulse train. (To avoid confusion only one digit register is shown in Fig. 513.) Each digit register switch is wired to the banks of a pulse send switch (PS) in such a way that the correct electrical conditions are applied to four consecutive contacts of the latter. Thus, if the thousands digit is, say, 5, the wipers of the register switch (DR) are stepped to the 6th contact, and the following conditions are applied to contacts 2, 3, 4, and 5 of the pulse send switch bank:

Contact	$PS1$ Bank (− Line)	$PS2$ Bank (+ Line)
2	—	Earth
3	Earth	5000 Ω battery
4	—	Earth
5	Earth	100 Ω battery



Digit Dialled	1	2	3	4	5	6	7	8	9	0
Pulses sent out	+		+			+		+		
	—	▬	▬	—	—	—	▬	▬	—	—
				+					+	
	—	—	—	—	▬	▬	▬	▬	▬	—
Decoding Relays Operated	LP		LP			LP		LP		
	LN	HN/LN	HN/LN	LN	LN	LN	HN/LN	HN/LN	LN	LN
				LP					LP	
	LN	LN	LN	LN	HN/LN	HN/LN	HN/LN	HN/LN	HN/LN	LN
Storage Relays Operated	W		W			W		W		
		X	X				X	X		
				Y					Y	
					Z	Z	Z	Z	Z	
Display Lamps	1	2	3	4	5	6	7	8	9	0

FIG. 513. PRINCIPLE OF CODE SIGNALLING ON JUNCTIONS TO CALL INDICATOR MANUAL EXCHANGE

The hundreds, tens and units digits are similarly wired to consecutive groups of four contacts on the *PS* banks. When all digits have been received, the pulse send switch is driven at 10 steps per second, and during its passage over the bank contacts it transmits the appropriate light +, light −, and heavy − signals which correspond with the four digits set up on the registers. Thus, if the first digit is 5, the conditions on the *PS* banks send out

No pulse
Light negative
No pulse
Heavy negative

as the wipers move over contacts 2 to 5.

At the manual exchange the junction is terminated by three relays which are designed to respond to the various signalling conditions. The *LP* relay is polarized by means of a permanent magnet so that it responds only to + pulses (i.e. earth on + wire, battery on − wire). Relay *LN* is polarized in the opposite direction, so that it responds to − pulses (i.e. earth on − wire, battery on + wire). Relay *HN* is not polarized but has marginal adjustments, so that it will not respond to the light − or light + pulses, but requires the heavy − pulse for its operation. The relays have a single make contact and are of a modified design which facilitates accurate adjustment of the operate current. Fig. 514 shows the design of the polarized relays (*LN* and *LP*). The non-polarized (but marginal) *HN* relay is of similar construction, except that there is no permanent magnet and the coil extends the full length of the yoke.

The signals received over the junction are used to operate combinations of four storage relays *W*, *X*, *Y*, and *Z*, and the contacts of these relays are arranged in tree formation to light the display lamps. (The principle of using four relays to store 10 digits has already been described in Chapter VI.) The circuit is arranged so that only the *LP* and *HN* relays directly energize the storage relays, the *LN* relay being used to switch the *LP*1 and *HN*1 contacts from one pair of storage relays to a second pair. Receipt of a light − pulse operates contact ***LN*1**, which in turn energizes relay *QS*. At the end of the pulse, the restoration of *LN*1 allows relay *QA* to operate and hold in series with *QS*. Contacts ***QA*1** and ***QA*2** switch the connexions of the *HN*1 and *LP*1 contacts. Thus:

The first application of a light + pulse operates relay *W*.

The first application of a heavy − pulse operates relay *X*.

If a light + pulse is received after a − pulse, the operation of ***LP*1** energizes relay *Y*.

If a heavy − pulse is received after a previous − pulse, the operation of ***HN*1** operates relay *Z*.

The last signal of each digit is a − pulse (either heavy or light) and the second operation of contact ***LN*1** releases relay *QA*. The release of this relay rearranges the circuit so that the *HN*1 and *LP*1 contacts are applied to a second group of *W*, *X*, *Y*, and *Z* relays in readiness for the next digit. (These contacts are not shown in Fig. 513.) The detailed circuit arrangements are somewhat more complex and are considered later.

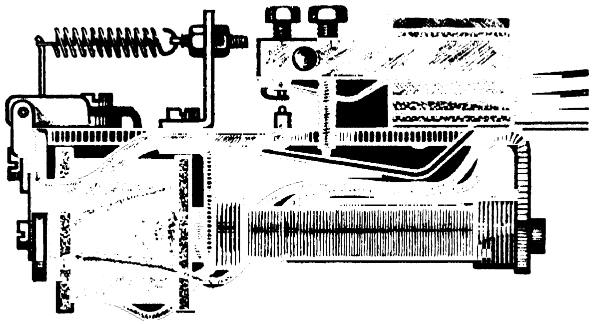


FIG. 514. TYPICAL POLARIZED RELAY AS USED ON C.C.I. SYSTEM

Trunking Arrangements of C.C.I. System. Fig. 515 shows the apparatus involved on a call from a director automatic exchange to a manual exchange with coded call indicator (C.C.I.) facilities. The system employs a *coder* at the automatic exchange which is designed to store the impulse trains sent out by the director and, when the equipment at the manual exchange becomes available, to re-transmit the stored impulse trains in the form of light and heavy current pulses along the junction wires. The arrangements at the manual exchange are somewhat complex due to the inclusion of extensive facilities for the even distribution of traffic amongst the various operators and for ensuring that the calls are dealt with in the order in which they originate.

The call from the automatic subscriber is passed to the director in the normal way (see Chapter XIII). After receipt of the complete code digits, the director pulses out the required trains of Strowger impulses to step the code selectors in the local exchange. In some cases the call may be routed through one or more tandem centres, and in such circumstances the director sends out further trains of Strowger impulses to position the

tandem selectors. The outgoing junctions to the required manual exchange are accessible from a certain level of code or tandem selectors, and each junction is provided with an outgoing relay set, known as a *C.C.I. relay set.* A 25-point uniselector (the *coder hunter*) is provided per C.C.I. relay set. When the C.C.I. relay set is seized, it causes the coder hunter to search for a free *coder.* A signal is sent back from the C.C.I. relay set during this period of search to restrain the director from sending out further impulse trains. Immediately a coder is associated with the C.C.I. relay set, the director resumes the pulsing out of the numerical calls are distributed evenly over the positions of a suite. To provide this facility, a *position load distributor* (P.L.D.) is provided for each suite. The position load distributor and its associated relay set (the *position load relay set*) are arranged to remove an artificial busying condition from the disengaged P.T.R. sets of one position at a time. Thus, by stepping the P.L.D. after each call, it is possible to distribute the incoming traffic to all staffed positions of the suite in cyclic order. The seizure of a free position trunk relay set causes one of two *markers* associated with the position to hunt for the P.T.R. set. The marker used on any

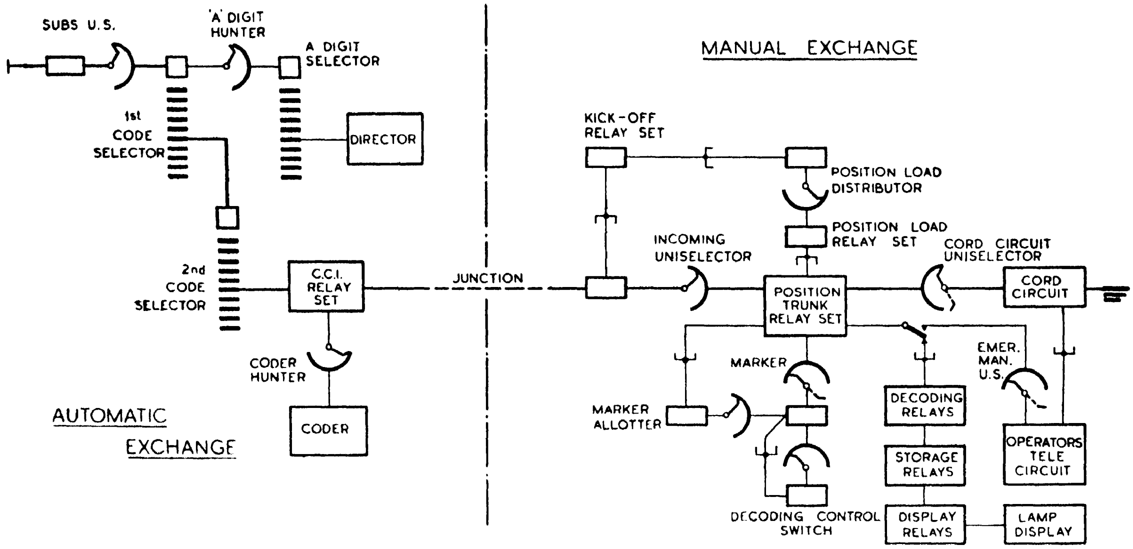


FIG. 515. GENERAL TRUNKING ARRANGEMENTS OF C.C.I. SCHEME

portion of the number required. The four numerical digits are transmitted to the coder in the form of Strowger impulse trains and are there stored, pending the re-transmission of the number in the form of coded pulses over the junction to the manual exchange.

At the manual exchange, each incoming junction is terminated on an incoming uniselector. When the junction is taken into use by the seizure of the C.C.I. relay set at the automatic exchange, the incoming uniselector hunts for a free *position trunk relay set.* The cross-connexion arrangements are such that each incoming uniselector has access to trunk relay sets distributed over all the positions of a C.C.I. suite. (A C.C.I. suite has a maximum of 15 positions.) Any incoming call can, therefore, be routed to any staffed position of the suite.

It is very desirable to arrange that the incoming particular call is pre-determined by a *marker allotter,* which ensures that the incoming calls are dealt with in the order in which they are received.

There is a *decoding relay group* per position and when this group becomes free, the *decoding control switch* steps to the marker which has been taken up and causes the decoding relay group to be associated with the incoming junction via the incoming uniselector and P.T.R. set. A signal is now passed back to the coder at the automatic exchange to indicate that the transmission of coded pulses can proceed. The pulses from the coder are received in the decoding relay group which, in turn, sets up the required conditions in a *storage relay group.* In addition to the storage relay group, there is a group of relays associated with the lamp display (the *display relay group*). When one call has been completed, the display

relay group is free to receive a further call, and the next call to be dealt with is now transferred from the storage relay group. The contacts of the relays in the display relay group light the appropriate lamps in the display panel, and the operator, on seeing the display, takes up any one of the 36 cords on the position. After carrying out the normal engaged test, she establishes the connexion to the required line in the outgoing multiple. The completion of the sleeve circuit causes a uniselector associated with the particular cord to search for the P.T.R. set through which the display originated. When this is found, the called subscriber is rung, and the display relay group is released. The call now proceeds in the usual manner and is taken down by the telephonist when the supervisory lamp glows at the end of the call. If the required subscriber is engaged, the operator presses the "busy" key on her position which causes the P.T.R. set to return busy conditions to the calling subscriber and to release the display relay group.

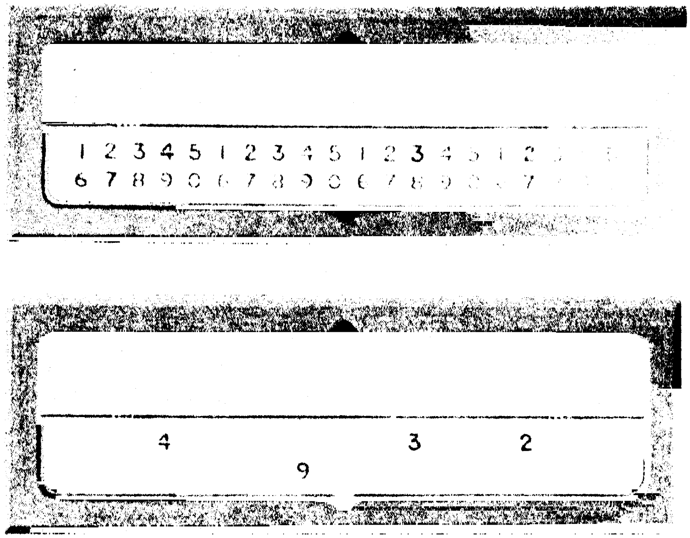


FIG. 517. ARRANGEMENTS OF DISPLAY PANEL ON C.C.I. POSITION

The C.C.I. system is expressly designed to provide an even flow of traffic to the operators at the manual exchange by the provision of call storage facilities. The scheme described above provides for:

1 call in the display relay group
1 call in the storage relay group
1 call in the decoding relay group
2 calls in the position trunk relay sets.

Under busy conditions, therefore, a total of 5 calls can be lined up in readiness for the attention of each operator. In addition, the coders provide facilities for holding back further calls until free position trunk relay sets become available. Even if all the coders are engaged, the call is not lost but is temporarily stored in the director.

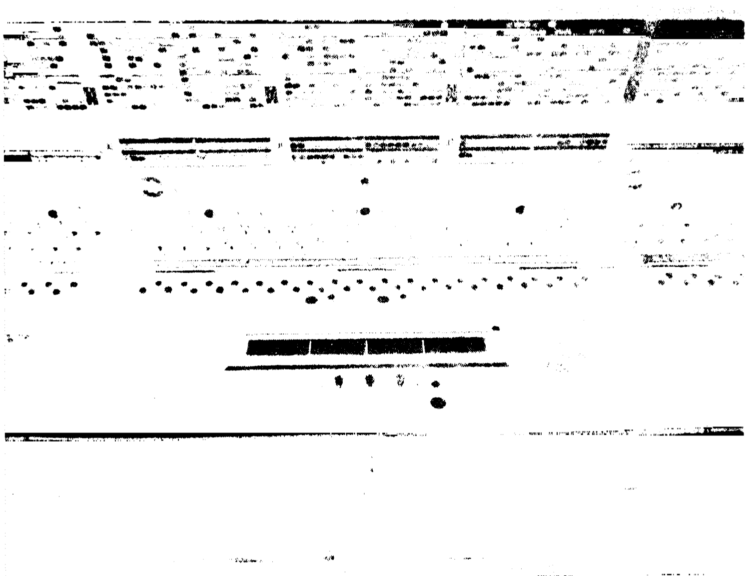


FIG. 516. C.C.I. POSITION AS SEEN FROM ABOVE

Fig. 516 gives a general view of a C.C.I. position at a C.B.I. exchange whilst Fig. 517 shows the display panel in more detail. Each display consists of 4 groups each of ten lamps located behind numerical stencils. The stencils are covered by a ground-glass screen (lower illustration) so that only the illuminated numerals are visible. A duplicate display is provided to prevent the immobilizing of a position due to a lamp failure. Either display can be exposed by moving a hinged metal plate.

C.C.I. Relay Set. The C.C.I. relay set comprises a coder hunter and 5 relays. When the circuit is seized from a selector level, the relay set:

(*a*) causes the coder hunter to search for a free coder;

(*b*) reverses the battery and earth conditions on the speaking pair until a free coder is found, in order to restrain the director from pulsing out;

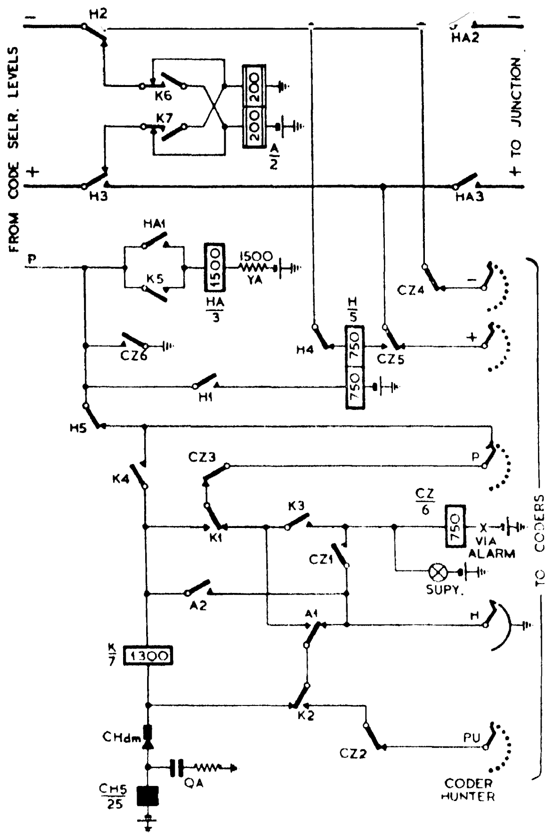


FIG. 518. C.C.I. RELAY SET

(*c*) repeats the impulses received from the director into the coder;

(*d*) switches the coder pulsing-out wires to the junction when required;

(*e*) releases the coder and switches the line through for conversation when pulsing out is completed.

Fig. 518 shows the circuit arrangements. The normal circuit conditions are such that earth is returned on the negative line and battery on the positive line. When the relay set is seized, this reversal of the usual conditions operates a relay (*D*) in the director to restrain the transmission of further impulses until such time as relay *K* operates. Relay *A* operates to the loop extended forward from the director. ***A*1** completes a circuit for the driving magnet of the coder hunter, which continues to search until a free coder is found. The *K* relay now operates via ***A*2** to the earth at the homing arc, and at ***K*1** extends a guarding earth to the *P*-wire. ***K*5** operates relay *HA* which, at ***HA*2** and ***HA*3**, switches the junction to the coder. Contacts ***K*6** and ***K*7** reverse the connexions of the *A* relay to line and, in so doing, signal to the director that the coder is ready to receive the impulse trains. These impulses are received on relay *A* and are passed forward (by *A*1) to the coder in the form of earth pulses over the *PU*-wire. When pulsing-in is completed, the coder sends out the appropriate coded signals over the junction and, when this operation is completed, the coder applies an earth to the pulse wire to operate relay *CZ* in the C.C.I. relay set. The contacts of *CZ* release the coder, but the C.C.I. relay set is still held.

In due course the operator at the C.C.I. position receives the display, and the completion of the call at the manual exchange causes the operation of relay *H* from the battery and earth returned by the cord circuit. *H* in turn breaks the circuits for relays *A* and *K*, and completes the switching to the junction. The coder hunter now homes and the C.C.I. relay set is held by the energization of relays *H* and *HA* from the earth on the *P*-wire.

Should a fault occur on the junction subsequent to pulsing out, relay *H* will fail to operate. In due course, the calling subscriber will release the faulty call, but relay *CZ* remains operated over the circuit provided via ***CZ*1** to the homing arc. ***CZ*6** busies out the relay set, whilst the prolonged operation of the *CZ* relay provides a deferred alarm.

The Coder. The coder consists essentially of 4 storage uniselectors together with a 5th uniselector mechanism which functions, firstly as a digit distributor, and then as a pulse send switch. The digit storage uniselectors are positioned by the incoming impulse trains from the director and, when conditions are appropriate for transmission of the coded signals, the pulse send switch rotates at 10 steps per second under the control of impulse machine springs.

When the coder is seized, the application of an earth to the *P*-wire from the C.C.I. relay set operates relay *SM* (Fig. 519). *SM* in turn operates *G*, and ***G*1** completes the circuit of the pulse wire. The first (thousands) impulse train is transmitted to the *M* uniselector, relay *SP* operating in parallel with the driving magnet. Contact ***SP*2** connects earth to the driving magnet of the pulse send uniselector, but the switch does not step at this stage. At the end of the first impulse train, relay

SP (which is made slow-to-release by the short circuit across its 200 Ω coil) restores. *SP*2 disconnects the pulse send switch driving magnet and causes the wipers to step to the second contacts. The *PS*5 wiper now transfers the pulse wire to the hundreds digit register switch, and the operation is repeated for the hundreds, tens, and units digits.

When the units digit has been received, the *LS*1 operates *SP* which holds after the release of *LD*1 through the circuit provided by the impulse springs. *SP*1 therefore releases during the first break period of the springs. This ensures that the driving magnet of the pulse send switch is connected to the impulse springs when they are open, thereby avoiding a clipped first impulse.

The wipers of the pulse send switch are now

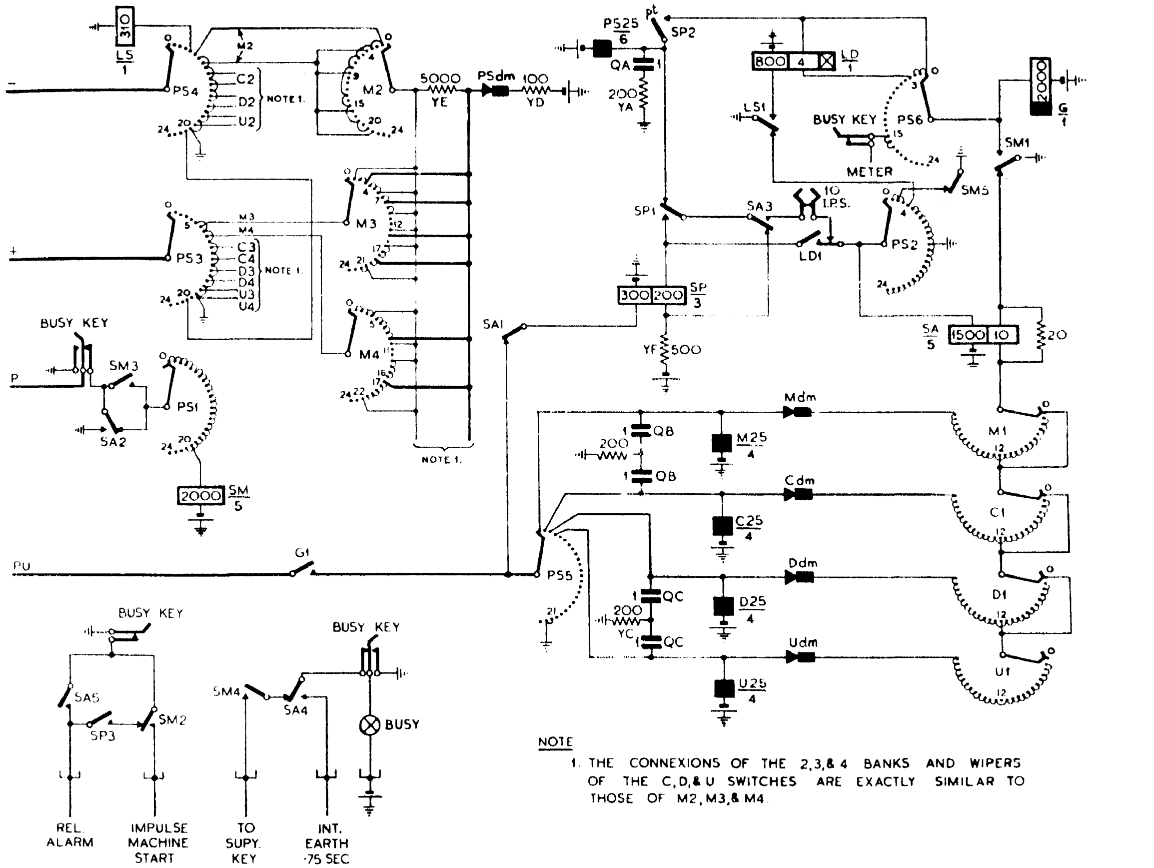


FIG. 519. CIRCUIT ARRANGEMENTS OF CODER

wipers of the pulse send switch connect relay *LS* to the negative line. *LS* operates by the current received over the junction when a free trunk relay set has been found, and at ***LS*1** completes the circuit for the 800 Ω coil of *LD*. Relay *SP* cannot operate at this stage, and the circuit remains in this state until the apparatus at the manual exchange is ready to receive the coded pulses. When this occurs, the three decoding relays are connected across the speaking pair in place of the battery and earth hitherto connected. Relay *LS* now releases and at *LS*1 disconnects relay *LD* and operates relay *SA*. During the release of ***LD*1**, stepped round the bank contacts and pulses of light negative, heavy negative and light positive currents are transmitted to line in accordance with the conditions set up by the *M*, *C*, *D*, and *U* uniselector arcs. (In Fig. 519 the connexions of the thousands digit register only are shown, but those of the other three registers are similar.) The stepping of the pulse send switch to contact 21 connects earth to the pulse wire for the operation of relay *CZ* in the C.C.I. relay set. The coder is now released in the manner already described, and the various uniselectors return to their home positions.

Distribution of Traffic at the Manual Exchange. The incoming uniselector at the manual exchange is of the non-homing type. Up to 50 position trunk relay sets are provided per C.C.I. position and a

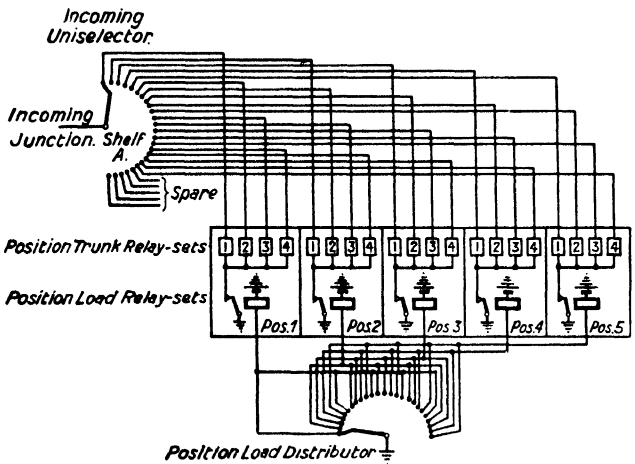


FIG. 520. METHOD OF DISTRIBUTING TRAFFIC AMONGST THE STAFFED POSITIONS AT A C.C.I. EXCHANGE

cross-connexion field is included so that each incoming uniselector is given access to position trunk relay sets associated with each position of a complete suite of 15 positions.

One position load distributor is provided per suite, and predetermines the position on which an incoming call is to be received by removing an artificial busying condition from the free P.T.R. sets of one particular position. An incoming call will therefore be received on a free trunk relay set associated with the particular position held open by the position load distributor. When this call is received, the P.L.D. steps to the next position, so allowing the position load relay set to replace the busy common on the position in which the call has been received, and opening the next position. Fig. 520 shows the scheme in diagrammatic form. For simplicity it is assumed that the exchange has 5 C.C.I. positions, and that a certain shelf (shelf A) of the incoming uniselectors has access to 4 position trunk relay sets of each position. If a call is received over any one of the 25 junctions terminated by the uniselectors on shelf A, the incoming uniselector associated with that junction will hunt for and seize one of the position trunk relay sets on position 1. The position load distributor then steps to position 2, thereby opening that position and closing position No. 1.

The incoming uniselector has access to a maximum of 25 position trunk relay sets. Only a few of these are, however, opened at any one time by the position load distributor. Facilities are provided so that, if an incoming uniselector fails within a reasonable time to find a free P.T.R. set of the position opened for traffic, the P.L.D. is automatically stepped to open up the next position. If any position is unstaffed, the associated P.T.R. relay sets are automatically engaged.

Control of Decoding. Each C.C.I. position is provided with two markers. The marker is a 25-point uniselector with the wipers arranged for double search, i.e. they give access to a total of 50 bank contacts. At the appropriate time the marker hunts for and marks the particular P.T.R. set taken into use by an incoming uniselector. The operation of the markers is controlled by a marker allotter which is a 25-point uniselector, and is provided to ensure that the markers shall be brought into use alternately. The marker allotter normally stands on the bank contacts of an idle marker, and when this marker has been taken into use it steps to the contacts of the other marker and prepares this one to deal with the next call. A further 25-point uniselector, known as the decoding control switch, is provided for associating the P.T.R. set held by each marker with the decoder in turn.

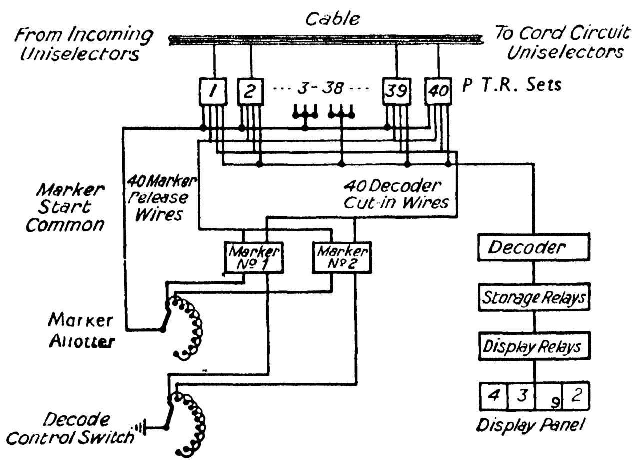


FIG. 521. DECODING CONTROL ARRANGEMENTS

Fig. 521 shows the arrangements in block diagram form. When one of the P.T.R. sets is seized by an incoming uniselector, a signal is transmitted over the marker start common and via the marker allotter to the predetermined marker. This marker hunts for and seizes the

P.T.R. set and the marker allotter then steps to the next marker. The decoding control switch subsequently steps to the bank contacts of the marker and connects earth via the marker wiper to a decoder cut-in wire of the P.T.R. set. The decoder is common to all the trunk sets of one position, and the earth on the decoder cut-in wire causes the particular trunk set to be connected with the decoder.

Position Load Distributor Circuit. Fig. 522 shows the main circuit elements involved in the association of an incoming junction with the decoding equipment. The position load distributor connects earth from *PC*1 to operate the guard control relay (*GC*) of the position load relay set of one particular position. ***GC*1** disconnects the earth from the position busy common, i.e. from the *B*1 contacts of all free P.T.R. sets of that position. The disengaged P.T.R. sets in the remaining positions of the suite are busied by the earth supplied to the position busy commons by the *GC*1 contacts of the position load relay sets of those positions.

When relay *LS* in the coder at the automatic exchange (Fig. 519) is connected to the negative wire of the junction, relay *L* of the incoming uniselector circuit (Fig. 522) operates, and this switch now hunts for a free P.T.R. set. When a free circuit is found, relay *K* operates, and at ***K*3** guards the circuit and also operates relay *PB* in the position load relay set. The 20 Ω shunt applied to the *L* relay by ***K*4** provides a slow-to-release feature to permit the operation of *PB* before *L*2 disconnects the circuit. The operation of *PB* transmits an earth via ***PB*2** and ***GC*1** to the position busy common, thereby closing the position to other incoming uniselectors which may be hunting. ***PB*1** completes the circuit for the *PL* driving magnet and for relay *PC*. ***PC*1** disconnects *GC* and *GC*1 applies earth to the position busy common. At the same time the *PL* driving magnet steps the P.L.D. wipers to the next contact.

If all P.L.R. sets of the position opened by the P.L.D. are engaged, their *B* relays will be operated and their respective *P*-wires will be connected to earth. Under these circumstances the incoming uniselector will be unable to find a free relay set, and it is necessary to step the P.L.D. to the next free position.

When relay *L* of the incoming uniselector circuit operates, the ***L*3** contact operates relay *SK* in a common kick-off relay set. ***SK*1** applies interrupted earth to relay *KA*. Relays *KA*, *KB*, *KC* and *KD* are two-step relays, and the current passing through their 100 Ω coils operates the "*x*" contacts only. Current passing through both coils operates the relay fully. The first application of interrupted earth operates the ***KA1*** contacts, and when this earth is removed the relay fully operates over both coils in series. The interrupted earth lead is now extended to relay *KB* and the process is repeated to operate relays *KB* and *KC* in sequence. *KC* therefore fully operates in from $3\frac{3}{4}$ to $4\frac{1}{2}$ sec after the initial operation of ***SK***. ***KC*** extends the interrupted earth to the ***KD*** relay and also operates relay *KCR*. The ***KCR*** contacts in turn operate the *GC* relays of all staffed positions in which there is a free marker and a free cord circuit. The **GC1** contacts of these relays disconnect the position busy common, so throwing open all the available staffed positions.

If this action still fails to make a free trunk relay set available to the incoming uniselector, the operation of relay *KD* some 1·5 sec later causes the concentration position P.T.R. sets to be made available. Contacts of the *KD* relay are arranged to give a visual and audible alarm.

Marker and Decoding Control Circuits. When the position trunk relay set is seized, the earth which is normally connected to the marker release wire is removed and an earth is placed on the marker start wire (see later). The marker allotter is standing on the bank contacts of the marker to be used for the call, and the marker start earth is extended to the start relay (*S*) of that marker. *S* operates and completes a hunting circuit for the marker uniselector which searches to find the P.T.R. set which is indicated by a battery on the marker release wire. Relay *K* now operates and the hunting circuit is disconnected. The ***K*1** contact disconnects relay *S* which releases after a delay period. An earth is now extended by ***K*2** to the marker release wire to operate relay *ME* in the P.T.R. set. The release of relay *S* removes the earth at *S*2, but, during the lag period of the *S* relay, relay *ME* returns an earth over the marker release wire to retain relay *K* and to busy the trunk set to the other marker. ***K*6** applies an earth via the *MD*1 bank to the driving magnet of the marker allotter.

The operation of ***K*3** energizes the start relay (*S*) in the decoding control switch circuit, and the switch hunts from the driving circuit provided by the earths on the bank contacts of the *DCS*1 arc. When the wipers step on to the bank contacts associated with the marker, the absence of earth arrests the hunting of the decoding control switch, and relay *K* in the decoding control switch circuit operates. ***K*1** now applies the earth from ***S*2** to the decoder cut-in wire and this in turn operates relay *IC* in the trunk relay set to connect the decoder to the junction which has seized that set. Contact ***K*2** operates the decoding control

relay (DC) which breaks the circuit of relay S to prevent the $K3$ contacts of other markers from operating the relay whilst the decoding control switch is handling the call under consideration. Before relay S releases and removes the earth at $S2$, relay IC returns an earth over the decoder cut-in wire to hold relay K in the decoding control switch circuit.

When both markers are in use, no calls can be received on the position. This state is known as the "position full" condition, and when it arises both marker K relays will be operated. The **$K5$** contacts disconnect the circuit of the full load relay FL (which is normally operated) and the $FL2$ contact applies earth to the bank contacts of the position load distributor. The latter now steps its wipers until a position is reached where a free marker is available. The $FL2$ contact provides a home position for the marker allotter to prevent continuous hunting under these conditions. The $FL1$ contact lights the "position full" supervisory lamp to give an indication to the supervisor of the congestion conditions. As soon as a marker is released, the restoration of the $K5$ contact re-operates relay FL which, in turn, opens the position to the position load distributor and steps the marker allotter off the last bank contacts. As described later, the "position full" condition can also arise due to all cord circuits on the position being in use.

When the decoder has been associated with the trunk relay set, a loop is returned to the coder at the distant automatic exchange so that pulsing out can proceed. When the decoder has completed its function, the earth on the marker release and decoder cut-in wires is removed by the trunk relay set. Relay K in the marker circuit and relay K in the decoding control switch circuit are now released. The restoration of $K2$ in the decoding control switch circuit releases DC, but an earth is applied via the $DCS2$ are to step the marker uniselector during the release lag of DC.

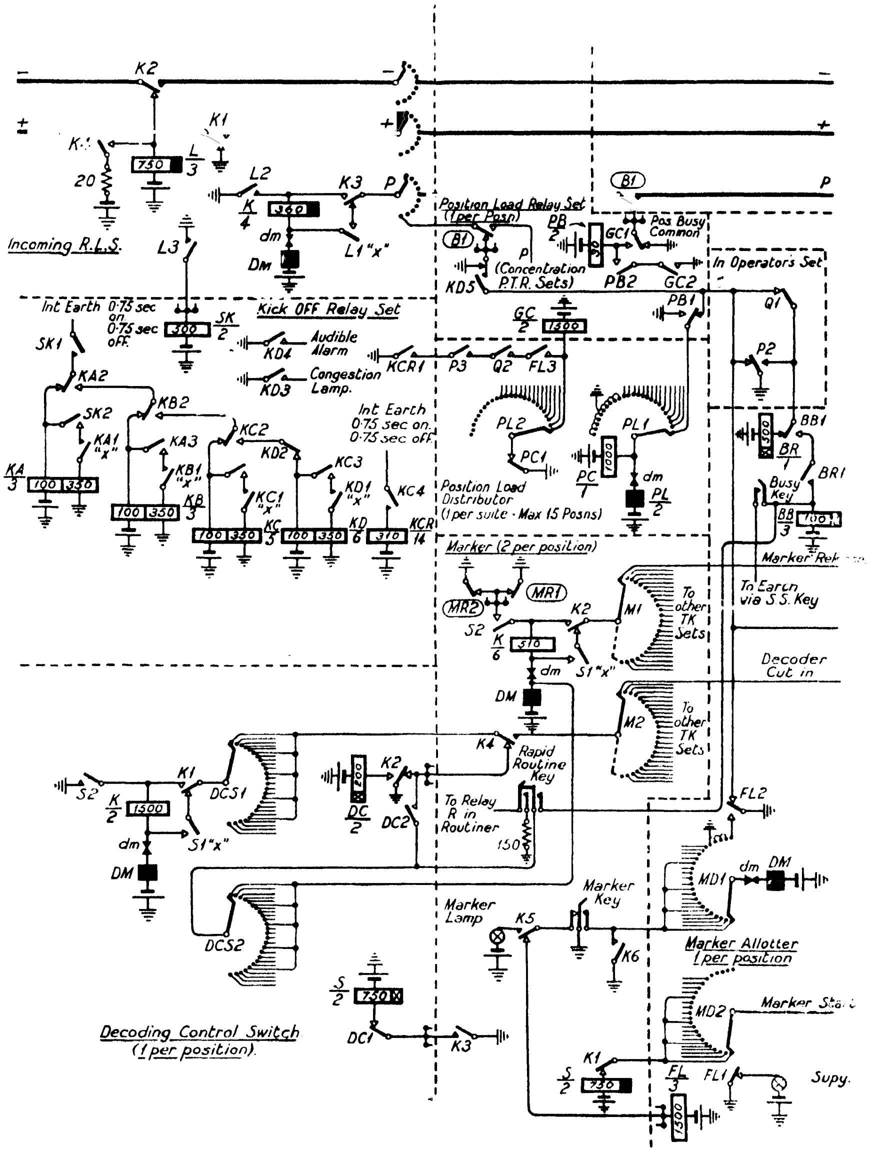


FIG. 522. INCOMING UNISELECTOR, POSITION LOAD DISTRIBUTOR, MARKERS, MARKER ALLOTTER AND DECODING CONTROL SWITCH

If the other marker has operated in the meantime, relay S will re-operate on the restoration of DC and the decoding control switch will hunt for this marker as already described.

Facilities are provided for busying out a faulty marker by the operation of a key on the C.C.I. position.

Position Trunk Relay Set. Fig. 523 (which is an extension of Fig. 522) shows the connexions of the position trunk relay set, the decoding, storage and display relay groups. When the P.T.R. set is seized, relay L is operated over the negative wire of the junction in series with relay LS in the coder. L operates LA and $LA1$ removes the earth from the marker release wire and connects the marker engaged relay ME to that wire. $LA4$ extends earth to the marker start common which is routed via the $MD2$ wiper (Fig. 522) to one of the two markers. This causes the marker to commence hunting for the P.T.R. set. $LA2$ applies earth to the P-wire and operates relay B. $B1$ (Fig. 522) switches the P-wire through to the trunk relay set to

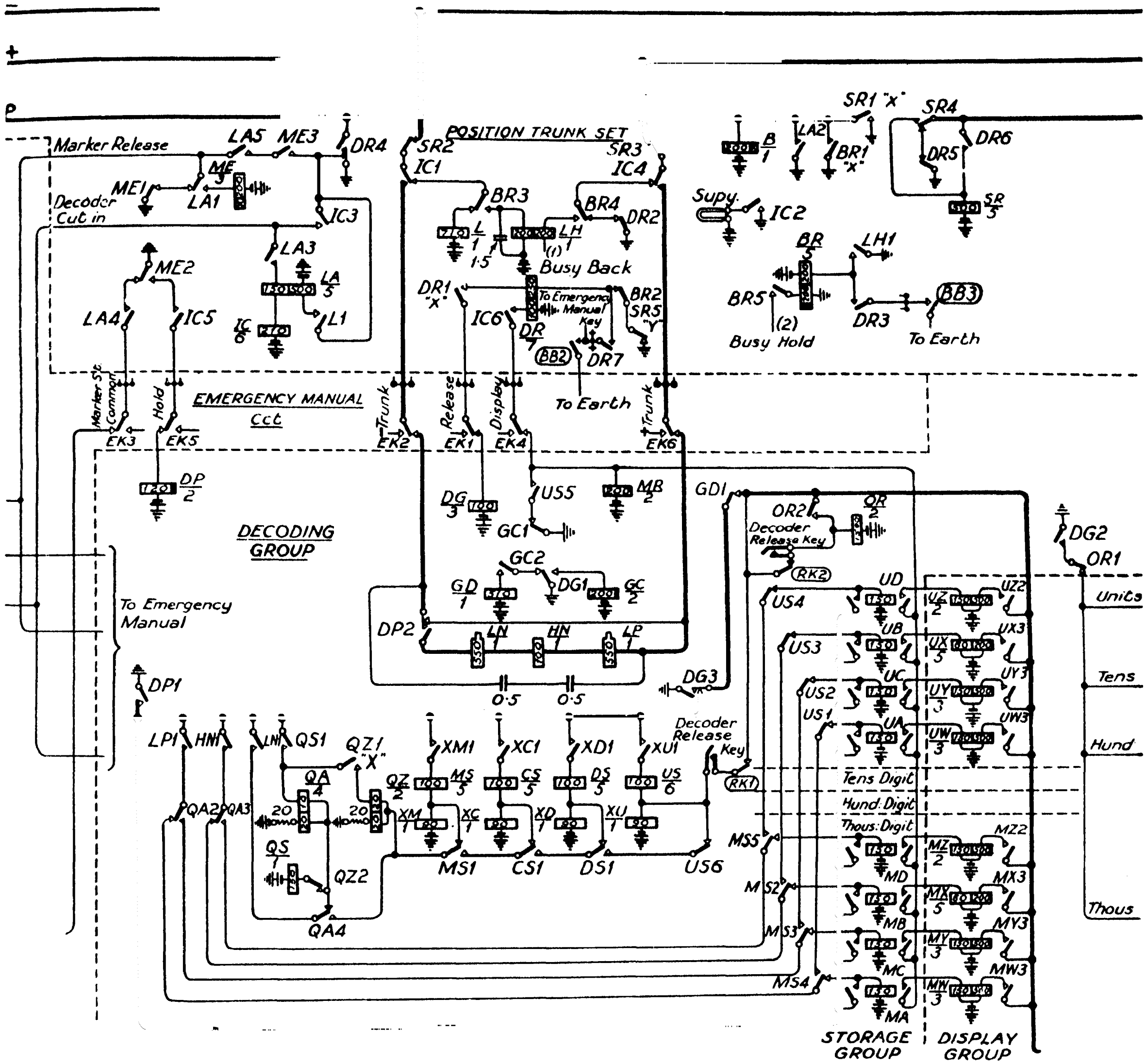


Fig. 523. Position Trunk Relay Set, Decoding Storage and Display Relay Groups

provide a holding condition for relay *K* in the incoming uniselector.

The marker pre-selected by the marker allotter hunts for the P.T.R. set and, when it has found the set, connects an earth to the marker release wire. *ME* now operates, and contact ***ME*2** disconnects the earth from the marker start common.

The circuit is now prepared for the decoding process. The stepping of the decoding control switch wipers to the bank contacts of the marker which is marking the P.T.R. set, causes an earth to be received over the decoder cut-in wire. Relay *IC* operates in series with one coil of relay *LA*. ***IC*3** provides a locking circuit for *IC* and *LA* and also returns an earth over the decoder cut-in wire to hold relay *K* in the decoding control switch circuit. Other contacts of the *IC* relay extend the junction to the polarized decoding relays, although the latter are at present short-circuited through contact *DP*2. ***IC*5** operates relay *DP*, but the latter is slow-to-operate. This allows any capacitance discharge currents from the junction to circulate via *DP*2 rather than to produce false operation of the decoding relays. Contact ***DP*1** provides the earth for the decoder, storage, and display relay groups.

Decoding Group. The lower portion of Fig. 523 shows the connexions of the decoding relay group. The principle of transmitting coded d.c. pulses over a junction, and the method of decoding such pulses to provide a lamp display, have been considered. The detailed circuit operation of the decoding relay group can best be understood by assuming that the initial digit is, say, 6. The coded pulses corresponding to this digit are light positive, light negative and heavy negative. On receipt of the light positive pulse, relay *LP* operates, and at ***LP*1** operates relay *MA* in the thousands digit storage group. Relay *LP* releases when the pulse send switch in the coder steps, and the next pulse received is a light negative one. This pulse operates relay *LN* which, in turn, energizes *QS*. Relay *LN* releases at the end of the pulse, and relay *QA* now operates due to the removal of the short-circuiting earth. The next and last pulse to be received is the heavy negative pulse, which operates both *HN* and *LN*. ***HN*1** operates *MD*, whilst ***LN*1** connects earth to relay *QZ*, the thousands digit switching relay *MS* and its auxiliary relay *XM*. *QZ* operates only its *X* contact at this stage, but *XM* operates fully. At the end of the pulse, relays *LN* and *HN* release to allow *QZ* to complete its operation. At the same time *MS* operates in series with *XM*. The *MS* contacts disconnect the thousands digit storage relays and connect the hundreds storage relays in readiness for the reception of the next digit. *QZ* disconnects *QS*, and *QS*1 in turn releases *QA* and *QZ* ready for re-operation on receipt of the next series of pulses. Relays *MS* and *XM*, however, remain operated to prepare the circuits of the hundreds digit storage relays.

The remaining 3 digits are decoded and stored in a similar manner to that described above. *US* operates on completion of the decoding of the units digit and, at ***US*5**, connects earth to the operated contacts of all the storage relays which have been energized during the decoding process. This causes the corresponding relays in the display group to operate and lock. If the previous display has not been cleared, however, relay *GC* is operated and ***GC*1** withdraws the earth from contact ***US*5** until the display relays are ready for the call. The circuit arrangements are such that a call can be stored in the storage relays whilst a previous call is being displayed. As soon as the displayed call is cleared, the second call is transferred from the storage relays to the display relays.

The operation of relay *US* also completes a circuit for the display ready relay (*DR*) and the marker release relay (*MR*). ***DR*4** removes earth from the marker release wire and from the decoder cut-in wire, to release the *K* relays in the marker and in the decoding control switch circuits. Relays *ME*, *LA*, and *IC* also release. *IC* in turn releases *DP*.

The operation of *DR* causes the operation of the display glow relay (*DG*). The contacts of *DG* provide a locking earth for the display relays independent of the earth from ***DP*1**. The release of *DP* allows the decoding and storage relay groups to restore in readiness for another incoming call.

Cord Circuits, Display Lamps, etc. Each C.C.I. position is equipped with 36 single-ended plugs, with each of which is associated a supervisory lamp. Every cord circuit terminates on a double search uniselector, which gives access to 50 P.T.R. sets. The display panel is mounted on the keyboard of the position, and in front of the display panel are 3 press button type keys marked *BB*, *REL*, and *SV* respectively. At the side of the *SV* key is a lamp also marked *SV*. There are 2 further lamps at the rear of the display panel marked "Pilot" and "Emergency."

Fig. 524 shows the connexions of the cord circuit, the operator's telephone circuit, and the display lamps. It has been seen how the operation of the *DG* relay connects earth at ***DG*2** to the display panel, thereby causing the lamps corresponding to the 4 digits of the called subscriber's number to glow. The operator picks up any one of the

disengaged cords (preferably one near to the called subscriber's multiple jack) and tests the bush of the multiple jack with the tip of the plug. If the line is free, the plug is inserted into the jack, and uniselector finds the P.T.R. set concerned, and relay *K* operates to cut the drive and switch the calling junction through to the cord circuit. (If the uniselector should fail to find the P.T.R. set,

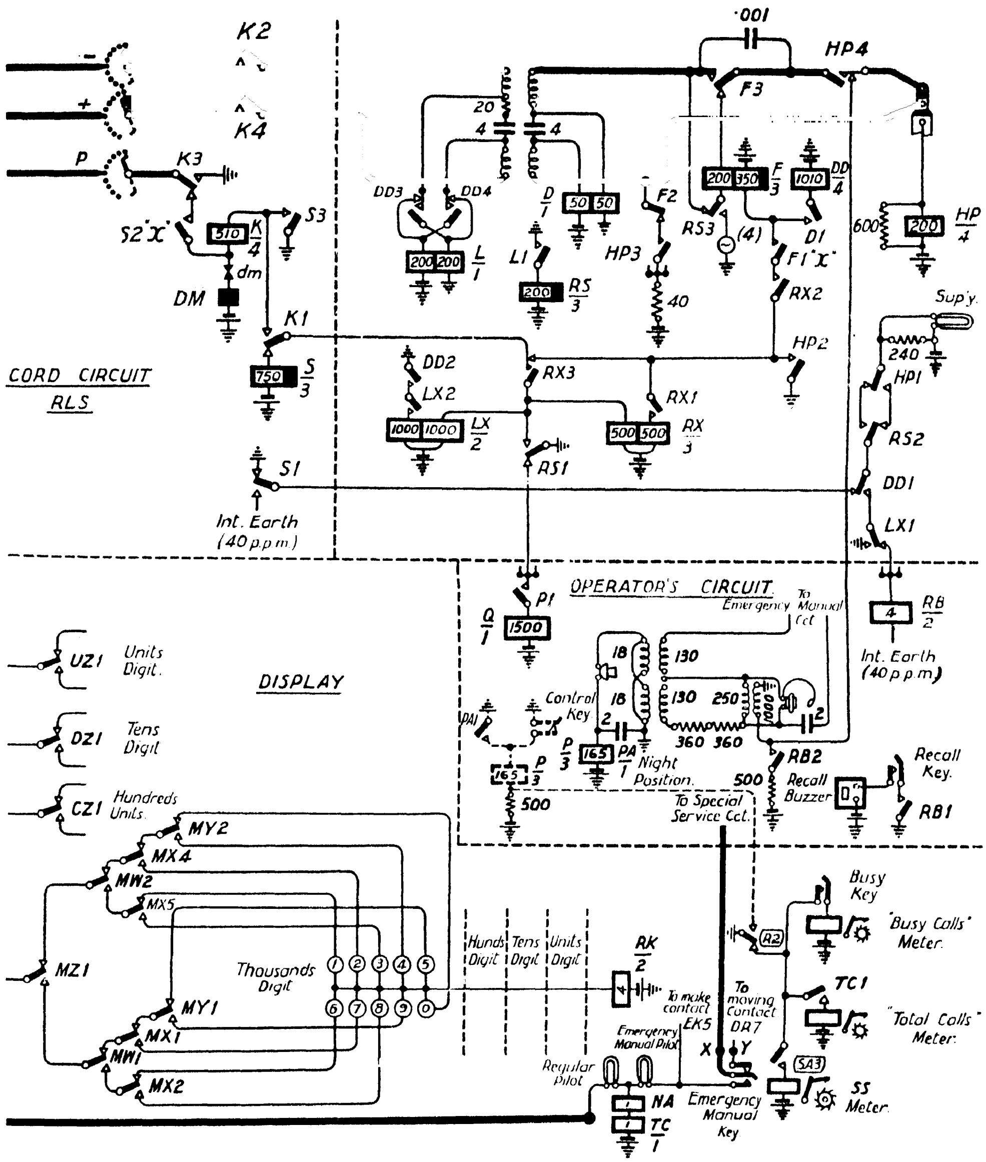


FIG. 524. CORD CIRCUIT, OPERATOR'S CIRCUIT AND LAMP DISPLAY

the sleeve relay (*HP*) operates. **HP2** operates relay *S* in the cord circuit uniselector circuit, and the *S* contacts provide a self-drive circuit for the uniselector. The **S1** contact extends interrupted earth (40 pulses per minute) to the cord circuit supervisory lamp. In due course the cord circuit the continuous flicker on the cord circuit supervisory lamp indicates this fact to the operator.) A loop is provided by relay *H* in the C.C.I. relay set at the distant automatic exchange, and this relay now operates from the battery and earth supply of the cord circuit. The operation of relay

H completes the switching at the automatic exchange. At the same time, relay *L* in the cord circuit operates, and at ***L*1** operates the ringer start relay (*RS*). ***RS*3** applies ringing to the called subscriber, whilst ***RS*1** energizes the ringing restart relay (*RX*) and the lamp relay (*LX*). ***RS*2** disconnects the supervisory lamp circuit.

When the called subscriber answers, relay *F* operates to trip the ringing current and extend the called subscriber's line to the transmission bridge. Relay *D* now operates and at ***D*1** energizes relay *DD*. ***DD*3** and ***DD*4** reverse the polarity of the battery and earth returned over the junction to provide metering against the calling subscriber.

At the termination of the conversation, *L* releases and *L*1 releases *RS*, and the latter lights the cord circuit supervisory lamp. The operator now takes down the connexion.

If the called subscriber is engaged, she depresses the *BB* key on her position which energizes relays *BB* and *BR* (Figs. 522 and 523). ***BR*2** disconnects relays *DR* and *DG* which release the display relays. Contacts ***BR*3** and ***BR*4** connect the line hold relay (*LH*) across the speaking pair, and busy tone and flash are returned to the calling subscriber. *LH* operates during the busy tone period to retain *BR*.

Other Facilities. The C.C.I. system provides a number of facilities which it is not possible to describe in detail. The more interesting of these facilities are:

Special Service Circuit. This circuit enables the operator to switch an incoming call to one of a number of special service positions by the operation of the *SV* key. This switching facility is necessary in cases where a mutilated display is received. Under certain fault conditions, a marker pilot signal is given to the operator but no display follows. She can clear her position by operating the decoder release key (marked *REL*) and by switching the call to the special service positions.

Emergency Manual Circuit. Should the decoder, storage, or display relay group become faulty, manual working can be adopted by throwing the emergency manual switching key. This key is mounted in the panel space above the multiple, and its operation enables the operator to take incoming calls on a purely oral basis.

Flashing Recall. Facilities are provided, whereby the called subscriber can produce a flashing signal on the cord circuit supervisory lamp should an outgoing call be required before the operator has cleared down a previous incoming call.

Direct Dialling From Manual Exchanges. We have examined the various methods of handling traffic between an automatic subscriber and a subscriber on a manual exchange. The methods of dealing with traffic in the reverse direction, i.e. from manual subscribers to automatic subscribers, is equally as important and is described in the following paragraphs.

The most obvious way of providing means whereby a manual exchange operator can establish a call to a subscriber on an automatic exchange is to provide a dial on each manual position, and a method of connecting this dial to any desired outgoing junction circuit. The arrangements must, of course, provide for the seizure of the equipment at the automatic exchange prior to impulsing, and for the holding of the connexion at the end of impulsing (i.e. when the dial is dissociated from the junction circuit). Traffic from manual exchange operators over junction routes to the automatic exchange differs from the traffic originated by local subscribers, in that the traffic carried per circuit during the busy hour is very much greater on junction routes. There is therefore little advantage in terminating an incoming junction on a uniselector (as is done with subscribers' lines) since the intensity of traffic is normally sufficient to justify the allocation of an individual 1st selector per junction. This in turn makes it possible for the operator to dial without first waiting for dial tone, and in fact it is usual to remove the dial tone from those 1st selectors which are directly connected to incoming junctions.

The method of associating the position dial with an outgoing junction circuit is largely determined by the arrangement of the signalling equipment at the manual exchange. On an exchange of the central battery type, the junction calling signal (battery on *B*-wire) is normally applied from the calling side of the cord circuit. The supervisory relay is also in the cord circuit, so that there is no necessity for any equipment in the outgoing junction termination. In these circumstances it is possible to associate the position dial with an outgoing junction by arranging the dial to be switched to the calling side of the cord circuit when required. In a magneto exchange, on the other hand, junction signalling conditions are not applied from the cord circuit but by means of auxiliary equipment inserted in the outgoing junction termination. The presence of this equipment makes it impossible to dial via the cord circuit, and it is necessary to provide an additional jack which gives access to the line side of the auxiliary equipment. In some cases the position dial is terminated on a plug so that the operator can connect the dial to any required junction by inserting the dialling plug in the supplementary jack of the junction circuit. Where the number of

outgoing junctions to automatic exchanges is small it is sometimes possible to provide a dialling key per junction so that the operator can set up conditions for dialling merely by throwing the dialling key of the appropriate junction. C.B.S.1 exchanges present a similar problem. On exchanges of the C.B.S.2 type, the junction signalling conditions are applied from the cord circuit as in the C.B. system, and it is possible to connect the dial to any outgoing junction via the cord circuit connexions. In this case, however, the resistance of the cord circuit elements prevents the establishment of the correct holding conditions when the dial is dissociated from the circuit. This problem key lights a guard lamp to warn the operator that the dial switching key is thrown and that the ringing supply is cut off.

Particular care must be taken to ensure that a false initial impulse is not transmitted to the automatic equipment during the setting up of the dial circuit. It is therefore necessary to provide a false impulse suppression circuit and to adhere to a rigid system of operating the various keys, etc. If this guard circuit is not fitted, there is a danger of a false impulse being transmitted to the automatic equipment during the insertion of the calling plug into the outgoing junction jack, and also when the ringing key is operated to connect the

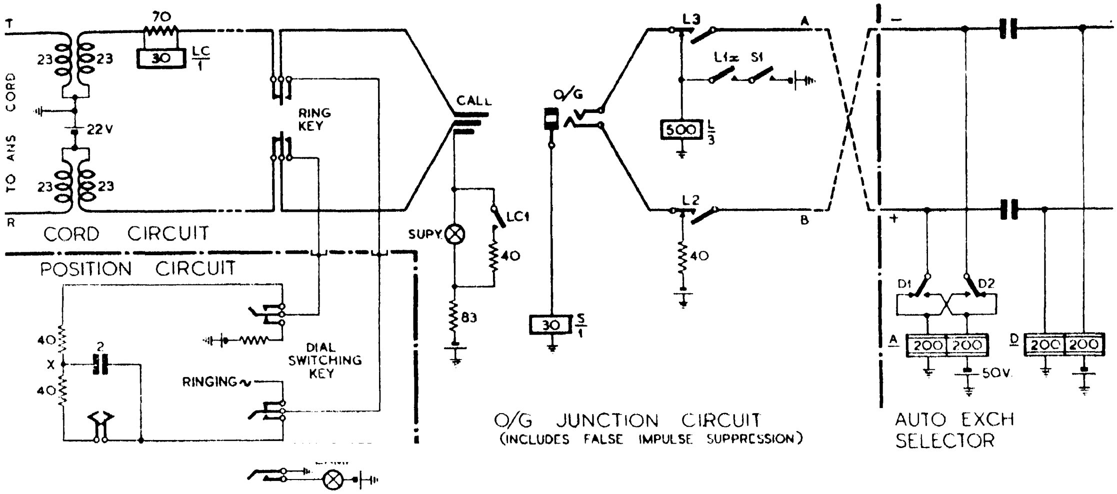


FIG. 525. METHOD OF DIALLING FROM A 22 V C.B. EXCHANGE

is also encountered on 40 V. C.B. exchanges, and in these cases it is necessary either to provide more or less complex outgoing junction equipment or, alternatively, to resort to single-wire impulsing over the junction.

Loop Dialling from C.B. Exchange. Fig. 525 shows the circuit elements involved on the establishment of a call from a 22 V C.B. exchange to an adjacent automatic system. Each cord circuit on the position is provided with a ringing key which, when thrown, connects ringing current to the tip and ring conductors of the calling plug. The position dial can be connected to any desired calling plug by providing a *dial switching key* (per position) which, when thrown, disconnects the ringing supply from all the cord circuits and replaces it by the dial circuit. The operator can therefore associate the dial with any outgoing junction by operating the dial switching key and then the ringing key of the appropriate cord circuit. An additional pair of contacts on the dial switching calling cord with the dial circuit. In order to guard against the application of ringing current to an outgoing auto junction, the operators are instructed always to throw the dial switching key before the cord circuit ringing key is operated.

When the calling plug is inserted into an outgoing auto junction, the battery on the sleeve of the plug operates relay *S* in the outgoing junction circuit. The earth and battery conditions from the cord circuit transmission bridge are now extended to the tip and ring conductors of the outgoing junction circuit, but contacts *L2* and *L3* prevent the seizure of the automatic equipment at this stage. The dial switching key is now thrown and is followed by the operation of the ringing key. The dial loop is now applied across the speaking pair, and relay *L* operates over this loop to the battery via the 40 Ω resistor. ***L1*** provides a locking circuit for *L* under the control of ***S1***, whilst ***L2*** and ***L3*** extend the loop to the outgoing junction. This loop operates the impulse accepting relay (*A*)

of the 1st selector at the automatic exchange which is now prepared in readiness for impulsing. The loop is disconnected during each break impulse at the dial contacts, the usual spark quench circuit being provided. At the termination of impulsing, the operator restores the ringing key and then the dial switching key. The impulsing loop from the dial is now removed from the junction but the A relay of the automatic exchange selector is now held over the — line by the current resulting from the difference in the voltages of the automatic exchange and manual exchange batteries. In due course the called subscriber replies and, by operating relay D, reverses the connexions of the A relay to line. Battery is now returned over the + wire of the junction to operate the supervisory relay LC of the cord circuit at the manual exchange. It will be noted that the automatic exchange selector is now held on one coil from the 50 V battery at the automatic exchange to the earth in the transmission bridge at the manual exchange, a further holding current being provided from the 22 V battery of the manual exchange cord circuit to the earth on the second coil of the A relay.

The available holding current under the *pre-answer* condition sets a definite limit on the junction resistance over which it is possible to adopt loop dialling from a C.B. exchange. If the automatic and manual exchanges are 50 V and 22 V respectively, there is a nominal potential difference in this holding circuit of 50 — 22 = 28 V. Conditions may arise, however, when the voltage of the automatic exchange battery is as low as 46 V and this may coincide with a high voltage (say, 24 V) at the manual exchange. Adverse resistance tolerances and possible differences of earth potential must also be considered. In practice it is necessary to restrict the junction resistance to 350 Ω (loop) in order to give a reasonable factor of safety during the pre-answer condition. This limit cannot be exceeded without reducing the hold current of the impulse accepting relay to a value which would produce abnormal distortion under leaky line conditions and a high susceptibility to mis-operation from line surges.

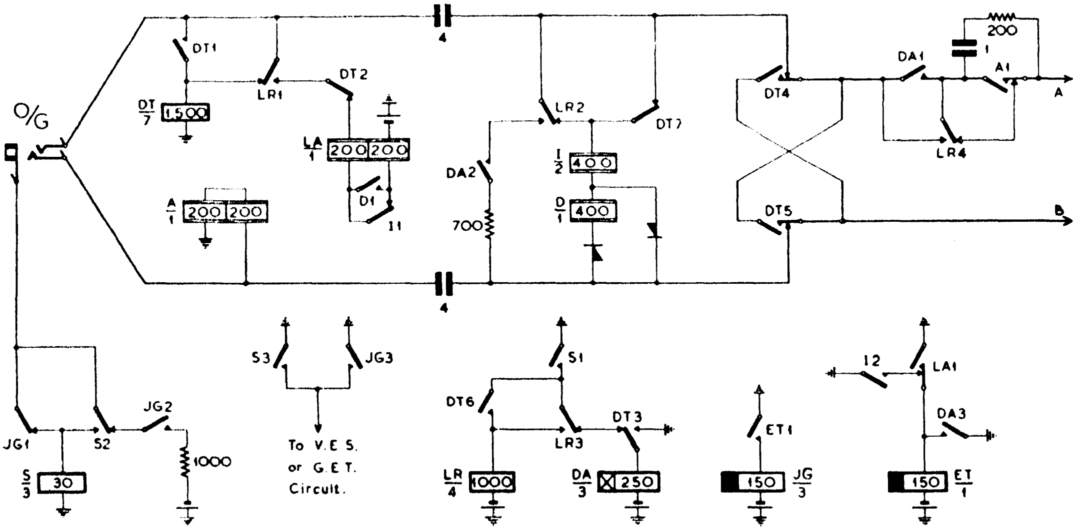


Fig. 526. Outgoing Loop Dialling Circuit at C.B. Exchange for Use on Long Junctions

It is clear that loop dialling direct from the cord circuit cannot be adopted when the manual exchange is of the 40 V type. The same applies to manual exchanges of the magneto and C.B.S. type where the exchange voltage may vary over comparatively wide limits.

The loop dialling limits imposed by pre-answer hold conditions can be eliminated by providing equipment in the outgoing junction circuit which effectively isolates the cord circuit from the junction holding loop. Fig. 526 shows a typical circuit specially designed with this object in view. Relay A operates to battery via the ring conductor of the cord circuit when a calling plug is inserted into the outgoing junction jack. Relay S also operates over the sleeve conductor, and at ***S*1** energizes DA. ***DA*1** completes the forward loop to the automatic exchange, whilst ***DA*3** operates relay ET. ***ET*1** energizes relay JG.

Battery is connected to the position dial circuit

(at point X in Fig. 525) so that, when the operator throws the dial switching key and the cord circuit ring key, relay DT operates to the battery extended over the tip conductor. Contacts **$DT4$**, **$DT5$**, and **$DT7$** disconnect the D and I loop, and prepare the impulsing circuit forward. **$DT6$** operates relay LR which, at **$LR4$**, removes the short circuit from the impulsing contacts $A1$. **$LR2$** also applies a 700 Ω resistor across the line capacitors to minimize surge distortion.

Relay A is now held from the battery via the dial impulse contacts, and at each break the release of $A1$ repeats the impulse to the junction.

answer holding difficulties can be overcome without the provision of isolating equipment in the outgoing junction termination by the use of a system of dialling over one wire of the junction circuit. This does, however, involve the provision of an incoming relay set at the automatic exchange to convert from the single-wire impulses to the normal loop impulses which are required to step the selectors. The impulse accepting relay in the conversion equipment at the automatic exchange is connected between the incoming — line and earth. At the manual exchange an earthed battery is connected to the dial circuit so that

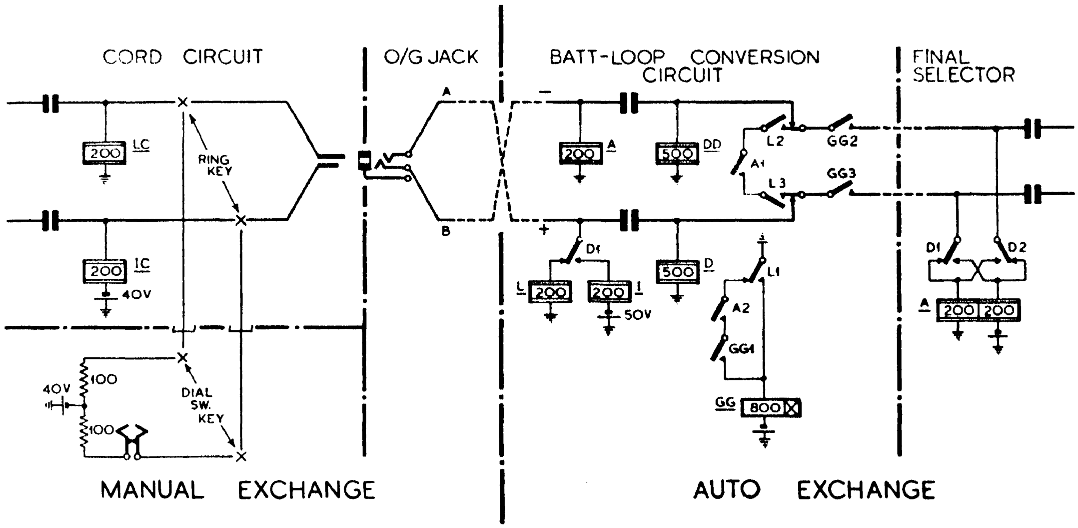


FIG. 527. PRINCIPLE OF BATTERY DIALLING FROM MANUAL EXCHANGE

At the termination of dialling, the restoration of the dial switching and ringing keys allows relay DT to release, and contact $DT2$ now connects the supervisory relay LA to the tip conductor. Other contacts of the DT relay disconnect the impulsing loop and restore the D and I relays. Relay I now operates to the forward loop current, and at **$I1$** disconnects the supervisory battery, thereby lighting the cord circuit supervisory lamp. When the called subscriber answers, the operation of relay D reconnects battery via LA to the tip conductor which, by operating the cord circuit supervisory relay, darkens the calling cord supervisory lamp. If engaged conditions are encountered, relay I responds to busy flash, and repeats the signal to the supervisory lamp.

Battery Dialling from C.B. Exchanges. Loop dialling relay sets of the type described above are fairly expensive and take up valuable accommodation at the manual exchange. They have, therefore, not been used to any great extent. The pre-

battery potential is applied to the — line via the dial impulsing contacts. The impulses transmitted over the junction are now disconnexions of this battery on the — wire. The method is therefore known as *battery dialling*. As in the previous scheme, it is necessary to provide a guard to avoid false impulses during the establishment of the dialling circuit. The guard in this case is provided by battery from the dial circuit which is applied to the + wire of the junction. The incoming relay set is arranged so that both this battery and the battery via the dial impulsing contacts must be received at the automatic exchange before the selector is seized.

Fig. 527 shows the principle of battery dialling from a manual exchange of the C.B. type. The insertion of a calling plug into the outgoing junction jack extends battery from the cord circuit over the — wire of the junction to operate relay A, but this relay is ineffective until relay L is energized at a later stage. The dial circuit is

associated with the junction in the usual way by the throwing of the dial switching and ringing keys. When this circuit is fully established, battery is extended via the dial impulse contacts to hold relay *A* at the automatic exchange. A similar battery is also transmitted over the + wire of the junction to operate relay *L*. ***L*1** now completes a circuit for relay *GG*, and contacts of the latter complete the loop to the 1st selector. During impulsing, relay *A* responds to the interruptions of the battery on the — wire and at *A*1 repeats the digits in the form of loop-disconnect impulses to the selector. At the termination of dialling, the restoration of the ringing key removes the battery from the + line of the junction and thereby releases relay *L*, relay *A* being held by the battery from the cord circuit via *IC*. The restoration of relay *L* disconnects the forward impulsing loop and provides an alternative holding circuit for the automatic selectors via relay *DD*. The circuit is now established for conversation, and in due course the called subscriber replies. The reversal of the line current from the final selector now operates relay *D*, and **D1** applies battery to the + line of the junction to operate the cord circuit supervisory relay *LC*.

Although battery dialling from C.B. manual exchanges was adopted primarily to overcome the pre-answer holding condition difficulties, the use of single-wire dialling does, in some cases, permit of impulsing over junctions of higher resistance than is possible with ordinary loop-disconnect impulsing methods. This is, of course, due primarily to the fact that the line resistance in the dialling circuit is halved by dialling over a single conductor. The use of battery dialling (or of any form of single-wire impulsing) has, however, a number of limitations which are discussed in Chapter XXII. In view of these limitations, the present trend is to avoid the use of battery dialling wherever possible.

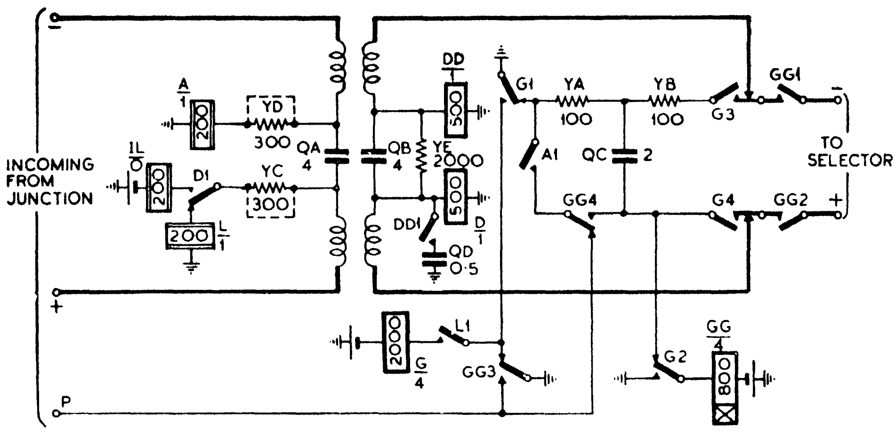


FIG. 528. DETAILED CIRCUIT OF INCOMING BATTERY DIALLING RELAY SET

Fig. 528 shows the complete circuit of a relay set suitable for terminating an incoming battery dialling junction from a manual exchange. The circuit provides for through supervision and the repetition of busy flash in addition to its major function of converting the battery pulses on the junction to loop impulses. Facilities are also provided for guarding an outgoing relay set when the circuit is used on a bothway junction.

The circuit is seized by the battery received over the — wire when a plug is inserted in the outgoing jack at the distant manual exchange. The **A1** contact applies earth to the *P*-wire to engage the outgoing portion of the circuit if the junction is being worked on a bothway basis. When the dial key at the remote exchange is operated, the battery transmitted on the + line operates relay *L* which, in turn, completes a circuit for relay *G*. **G2** operates *GG*. The operation of *GG* now completes (at ***GG*4**) the impulsing circuit. At each interruption of battery on the — line, relay *A* releases and at *A*1 provides a "loop-disconnect" impulse to the selector.

At the termination of dialling, the restoration of the dial key at the distant exchange removes the battery from the + line and so releases relays *L* and *G*. The circuit is now held by the retention of relay *GG* over the circuit provided by *G*1, **A1**, ***GG*4**, and *G*2. Relay *DD* operates from the battery at the selector *A* relay, and at ***DD*1** applies capacitor *QD* across the coil of relay *D* to allow the transmission of tone signals. The circuit is now established for conversation.

When the called subscriber answers, relay *D* operates to the reversal of the line current from the selector, and at **D1** returns battery over the + line to repeat the supervisory signal to the manual exchange operator.

Resistors *YC* and *YD* are provided to give the best impulsing conditions when the junction resistance is less than 600 Ω. If the circuit is used on junctions of higher resistance, these two

resistors are short-circuited in order to improve the impulsing performance. It will be noted that capacitor QB is shunted by a 2000 Ω resistor (YE) to prevent interaction between the relays due to discharge surges.

Dialling from Sleeve Control Manual Board. Dialling facilities are required from the automanual switchboard in order that the operator can complete incoming toll calls, assistance calls, and so on. The outgoing circuits to the automatic equipment appear in the outgoing junction multiple of the automanual board, and are usually provided with Free Line Signals. On sleeve control boards, the position circuit is normally arranged for loop dialling, and the outgoing junction circuit is designed so that the dial impulses can be transmitted to the automatic equipment without repetition. An additional facility is also provided on sleeve control boards, whereby an operator receives a flicker signal on the cord circuit lamp whenever she plugs into an outgoing dialling circuit. This signal reminds the telephonist that she must dial in order to establish the call.

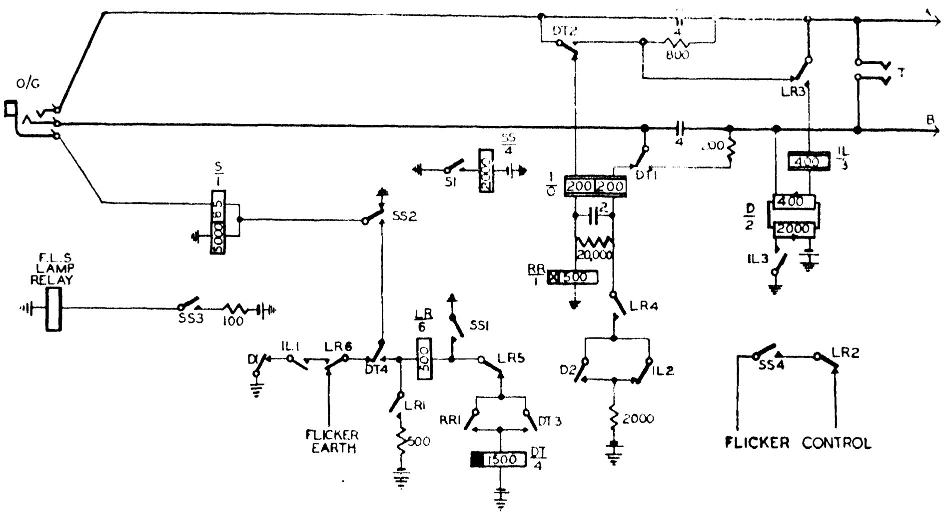


Fig. 529. Outgoing Loop Dialling Circuit at Sleeve Control Manual Board

Fig. 529 shows a typical outgoing circuit at a sleeve control manual board which is designed for loop dialling to an automatic exchange. This circuit, and a similar circuit arranged for battery dialling, have been described in Vol. I.

Keysending. The use of an ordinary telephone dial as a means of setting up calls to automatic subscribers from a manual switchboard is quite satisfactory where such calls form a small proportion of the total calls dealt with by the operator. As the number of dialled calls increases, dialling becomes somewhat slow and cumbersome, and a point is reached when it may be desirable to consider some alternative method for setting up calls via the automatic network. Such conditions often exist in a large city area when the programme of automatization has reached the stage where there are only a few manual boards in a network consisting mainly of automatic exchanges. Under these conditions as much as 70 or 80 per cent of the originated traffic at the manual exchanges may have to be routed by the operators to subscribers on nearby automatic exchanges.

The process of setting up a call to an automatic subscriber can be considerably speeded up by the provision of equipment which will generate the impulse trains necessary to step the selectors. It is, of course, still necessary for the operator to pass signals to the impulse generating equipment to notify the number required, but these signals can be of a momentary nature so that the telephonist is free to carry on with other work whilst the impulsing circuit is proceeding with the establishment of the call by means of normal loop-disconnect impulses. The simplest possible arrangement at the manual switchboard is to provide a group of ten push-button type keys (corresponding to the digits 1, 2, 3 . . . 0) and to arrange the equipment so that the operator can set up an automatic call merely by depressing the keys for the appropriate digits in quick succession. Thus, if an operator wishes to establish a call to an automatic subscriber whose number is 1234, she

depresses keys 1, 2, 3, and 4 in rapid succession. Signals are transmitted from the digit keys to special equipment which then proceeds to establish the call by means of ordinary Strowger impulse trains. The actual "keying-up" of the call may take no more than one or two seconds, as compared with upwards of four or five seconds if a similar call is established by means of a dial. This method of setting up calls by means of a keystrip is known as *keysending*, and the associated apparatus is broadly referred to as *keysender* equipment.

Keysender equipment may be entirely mechanical in operation or may involve the transmission of electrical signals to specially designed electromechanical apparatus. A simple form of keysender mission of the loop-disconnect impulses to the selectors. The application of this principle to keysending is illustrated in Fig. 530. The ten digit keys are arranged so that, when operated, combination signals are applied to four wires W, X, Y, and Z. The usual arrangement is as follows:

Digit	Combination	Digit	Combination
1	W	6	$W + Z$
2	X	7	$X + Z$
3	$W + X$	8	$W + Y$
4	Y	9	$Y + Z$
5	Z	0	$X + Y$

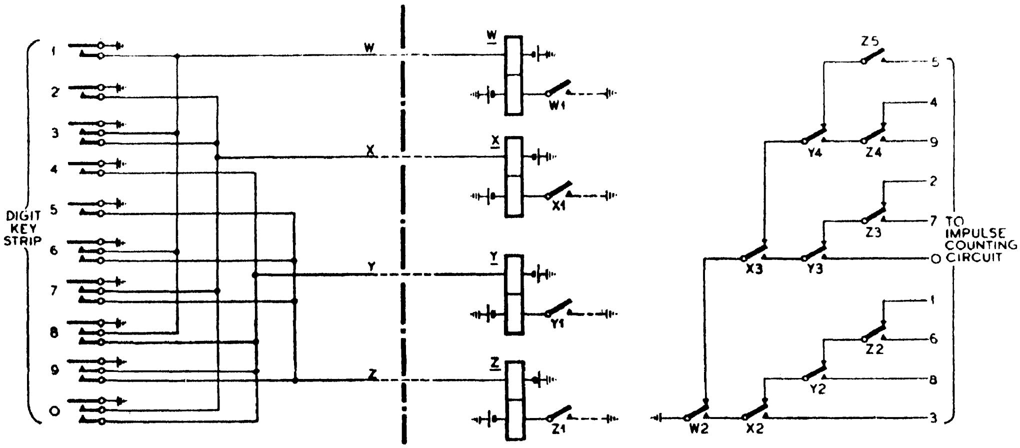


FIG. 530. PRINCIPLE OF ELECTRICAL KEYSENDER

of the mechanical type has already been described in Vol. I. This mechanism (Keysender No. 5) has 10 keys of the cash register type which control the positioning of a mechanism something on the lines of the mechanical impulse regenerator described in Chapter VI. The mechanical keysender is designed primarily for use at Private Branch switchboards in order to relieve the telephonist of the work of dialling public exchange calls. Such a mechanism is unsuitable for use at public exchanges where it may be necessary to key up a number of calls in rapid succession. (The mechanical keysender is designed so that a second call cannot be keyed up until the keysender has completed the pulsing out of a previous operation.)

Most electrical keysender systems are based on the principle (described in Chapter VI) that any one of ten distinctive digits can be stored by the operation of four relays in various combinations. The contacts of these relays can then be arranged to mark the appropriate contact of an impulse counting switch, which in turn controls the transmission of the loop-disconnect impulses to the selectors.

The signals operate relays W, X, Y, and Z in the correct combination, and contacts of these relays are arranged in tree formation to mark the banks of an impulse counting uniselector. Thus, if the digit key 6 is momentarily depressed, earth is applied to the W- and Z-wires, which results in the operation of relays W and Z. These two relays lock via contacts **$W1$** and **$Z1$**. The contact tree is arranged so that earth is extended via **$W2$**, $X2$, $Y2$, and **$Z2$** to mark terminal 6 of the impulse counting circuit.

Broadly speaking, there are three alternative arrangements of the keysending equipment:

(*a*) The conversion equipment can be located at the manual exchange. The wiring between the digit keys and the keysenders is now local, and the keysender equipment must be designed to transmit loop-disconnect impulse trains over the junction to the automatic equipment at a distant exchange. Although this method has been used to some extent, it has not been widely applied due to the difficulty of finding sufficient accommodation

and a satisfactory power supply at the manual exchange.

(*b*) The keysender conversion equipment can be located at the automatic exchange, and the W, X, Y, Z combination signals can be transmitted from the digit keystrip at the manual exchange over the junction circuit. This involves either

(i) the use of 4-wire junction circuits;

(ii) the adoption of directional and marginal d.c. currents over a 2-wire junction; or

(iii) 4 separate signalling frequencies for transmitting the various combinations over a 2-wire junction.

All three methods have been used in the past, but modern practice favours the use of voice-frequency signals (alternative (iii)). All of these methods depend upon the practicability of installing a digit keystrip on the existing positions at the manual exchange.

(*c*) The extension of auto calls from the manual exchange to a special keysending position associated with the automatic exchange. The circuits between the manual exchanges and the keysender positions at the automatic exchange can be worked on a signal basis, an order-wire basis, or, preferably, on the straightforward junction principle (S.F.J.). The advantage of this method lies in the fact that digit keystrips are not required on all A-positions at the manual exchanges. It also concentrates the keystrips, the keysender conversion equipment, and the automatic selectors at one point.

Keysender B-position Working. Fig. 531 shows the trunking arrangements of a keysender system in which the keying is applied from special B-positions located at the automanual exchange. The circuits between the manual exchanges and the keysender B-positions are worked on a straightforward junction basis. When a call is required for a subscriber on the automatic exchange, the A-operator at the originating manual exchange tests for and connects to a free outgoing junction in the usual way. At the automatic exchanges the incoming junctions are terminated on junction relay sets which are directly connected to 1st selectors. Any incoming junction can be associated with the keysender equipment by means of a link circuit which consists of an outlet relay set, a junction finder, and a sender hunter. On receipt of a calling condition, a signal is transmitted to the outlet relay set, and the latter causes the junction finder to search for the calling junction, and the sender hunter to search for a free sender. The seizure of a disengaged sender causes a position hunter uniselector to search for and switch the call to a free keysender B-position. A two-pip signal of 900 c/s tone is now returned to the originating A-operator to advise her that the B-position operator is in circuit and that she can proceed to pass a request. A white pilot lamp also glows on the B-position to indicate the connexion of a caller.

The A-operator now gives the number required to the B-operator, who sets up the call by the consecutive depression of the appropriate digit

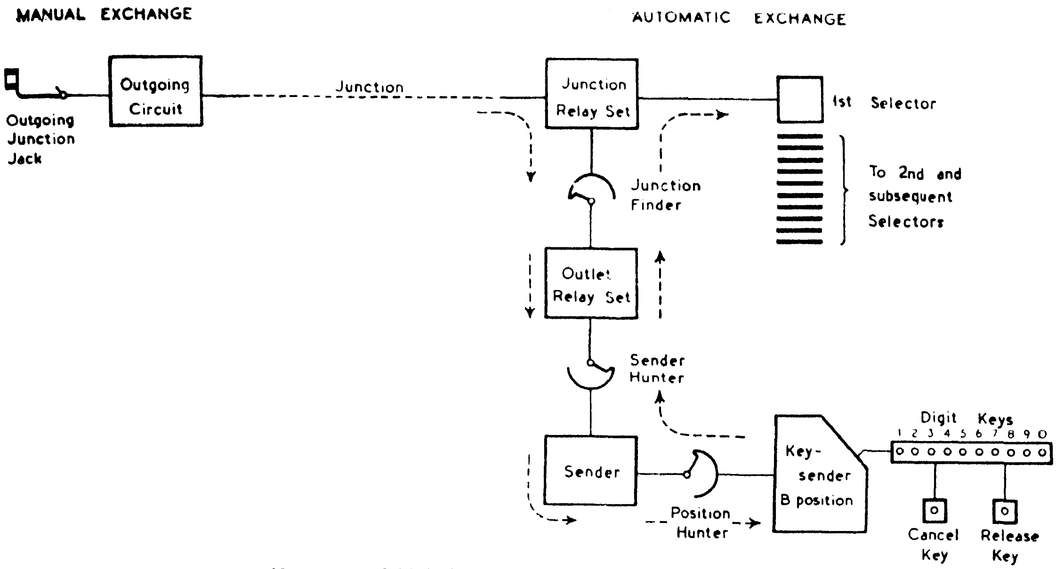


FIG. 531. S.F.J. KEYSENDER B-POSITION SYSTEM

keys. This operation transmits signals to storage relay groups in the sender. When the last digit key has been depressed, the B-position is automatically freed in readiness to receive further calls. The sender mechanism now proceeds to transmit normal loop-disconnect impulses which are routed via the outlet relay set and the junction relay set to the associated 1st selector. When all digits have been transmitted, the junction is switched through

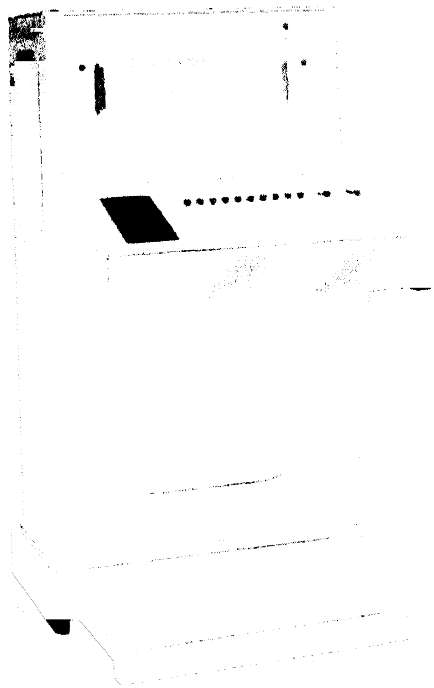


FIG. 532. KEYSENDER B-POSITION

to the selector, and the outlet, the sender and all the associated common apparatus are released for further use.

The keysender B-position is equipped with a cancel key so that the operator can obliterate any false set-up. There is also a release key, by means of which the B-position operator can free her position if it is seized by a distant operator but no number is demanded. A suitably calibrated traffic meter is provided to indicate to the supervisor the number of calls awaiting attention at the keysender B-positions. The circuit is arranged so that an audible warning is given if the number of waiting calls rises above a predetermined figure.

Fig. 532 shows the general design of the keysender B-position. There is no equipment apart from the digit keystrip, the cancel key, the release key, and the operator's telephone circuit.

Voice-frequency Keysending from A-positions. Fig. 533 shows an alternative method of keysending direct from the A-positions at the manual exchange by the use of voice-frequency signalling currents over the junction circuit. Apart from the provision of a digit keystrip per position and of a 4-frequency generator at the manual exchange, the trunking arrangements are substantially similar to those of Fig. 531. The keysender B-position is now replaced by a special relay set which is designed to detect the combinations of 4 frequencies transmitted over the junction and to convert these to d.c. signals which are returned to operate the storage relays in the sender.

The operator at the manual exchange selects a free outgoing junction to the required automatic exchange, and the normal junction calling condition causes the call to be extended to a disengaged voice-frequency relay set. The operator receives a two-pip signal of 900 c/s tone (as in the keysender B-position system), and the calling cord supervisory lamp at the manual position is darkened. The A-operator now depresses the start key associated with her digit keystrip to cancel any premature operation of the voice-frequency receiving relays. The manual exchange operator proceeds to key up the call and, when the last digit has been received, the V.F. relay set is released for further traffic. The required number is now set up in the storage relays of the sender, and the latter commences to establish the call by loop-disconnect impulses to the automatic selectors. At the completion of pulsing out, the junction is switched through to the selector train, and the outlet relay set, sender, etc., are released for further calls.

If the A-operator depresses a wrong digit key, she can cancel the call by operating the start key, provided that the last digit has not been keyed. If the error is discovered after this time, the calling plug must be withdrawn from the jack and a fresh start must be made.

Junction and Outlet Relay Sets. The upper part of Fig. 534 shows the circuit arrangements of the junction relay set used for terminating incoming junctions of an S.F.J. system. The lower part of the same diagram shows the outlet relay set which is required to provide a link between the junction and the sender.

When the operator at the distant manual exchange places a calling plug into the outgoing junction jack, the battery on the *B*-wire of the junction operates relay *L*. ***L2*** operates *B*, and ***B2*** in turn extends an earth over the assignment lead to operate the *SJ* relays of the associated outlet relay sets. (Fig. 534 shows only one outlet relay

set. In actual practice there are eight outlets accessible from each junction relay set.) The various *SJ* contacts extend the outlet relay set circuit to the wipers of the junction finder (*JF*).

The *P* bank contacts of all idle or engaged junction relay sets are connected to earth (at *B5* or ***BF2***). If, therefore, the wipers are standing on any such contacts, relay *G* operates via the 25 Ω coil of relay *K*. ***G1*** energizes the junction finder *KR* operates from the battery on the *P*-wire from the sender. ***KR2*** applies a low resistance guarding earth to the *P*-wire of the sender and, at the same time, holds *KR* on its 25 Ω winding. ***KR4*** and ***KR5*** now extend the positive and negative wires to the sender. Relay *JS* (of the junction relay set) operates from the earth at ***K1*** via the *P* wiper of the junction hunter. ***JS2*** operates *PS*, whilst ***JS3*** and ***JS4*** prepare the sender pulsing-out loop.

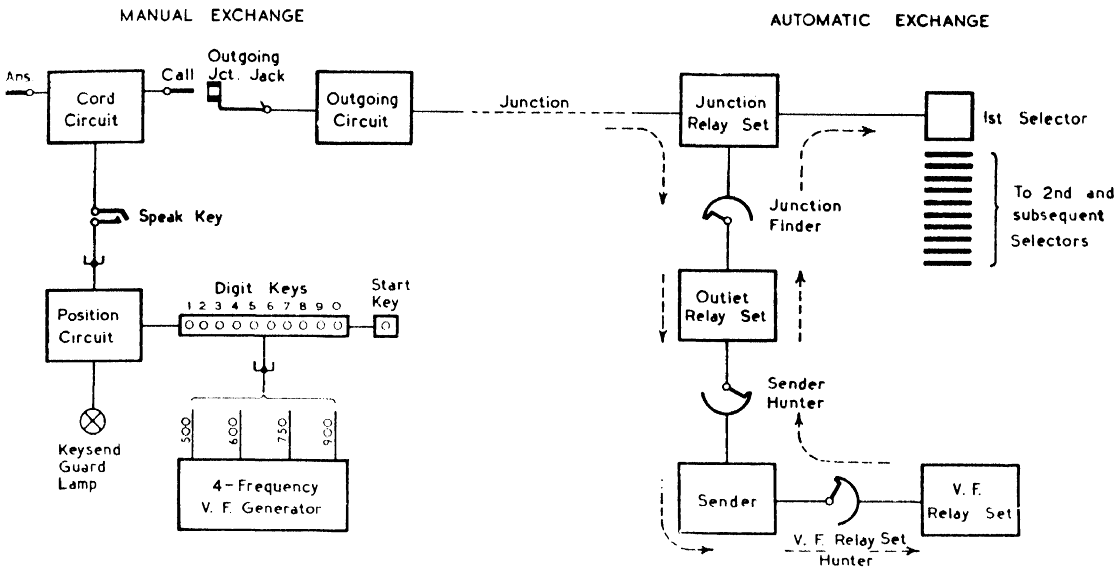


FIG. 533. VOICE-FREQUENCY KEYSENDING FROM MANUAL EXCHANGE A-POSITIONS

driving magnet, and the *JFdm* contacts operate when the magnet armature approaches the end of its stroke. The circuit of relay *G* is now disconnected, and the wipers are moved to the next contact. If the next contact of the *P* bank is similarly connected to earth, the junction finder continues to drive by the interaction of relay *G* and the driving magnet. When the calling junction is reached, relay *K* operates over both coils in series to the battery at the *JS* relay. ***K1*** applies a low resistance guarding earth to the *P*-wire, and holds relay *K* over the low resistance winding. ***K2*** operates the relief relay *KR*, whilst ***K3*** lights the "outlet engaged" lamp.

If the outlet on which the sender hunter wipers are standing is engaged, the earth on the *P*-wire operates relay *GS* in exactly the same way as relay *G* is operated. ***GS1*** energizes the sender hunter driving magnet, and the switch drives by the interaction of *GS* and the magnet until an outlet is reached where there is no earth on the *P*-wire. When a disengaged sender is encountered, relay ***JS5*** switches in the attenuation pad (if provided). The operation of ***PS2*** completes a circuit for the relief relay *PA*, and ***PA1*** applies a guarding earth to the incoming *P*-wire of the selector. ***PA2*** and ***PA3*** complete the positive wire circuit to the sender.

In due course the incoming junction is extended either to a voice-frequency relay set or to an S.F.J. B-position. Battery and earth are now returned over the negative and positive wires to operate relay *I* in the junction relay set. When the V.F. relay set or the B-position operator is ready to accept the call, the battery and earth connexions are reversed, and this reversal operates relay *D* in the junction relay set. ***D1*** now extends the battery from *LA* over the *A*-wire of the junction to darken the calling cord supervisory lamp at the originating manual exchange. Relay *LA* operates over this circuit.

The originating operator now either keys up the number required, or passes the number verbally to the B-position operator. The digits are stored

in the sender and are re-transmitted as Strowger impulses over the negative and positive wires to the first and subsequent selectors in the switching train. Before pulsing out is started, earth is to the inductance of *BF* and *JS* which limits the initial current in the circuit).

Contacts **BF4** and **BF5** now disconnect the *D* and *I* relays and extend the pulsing-out loop to

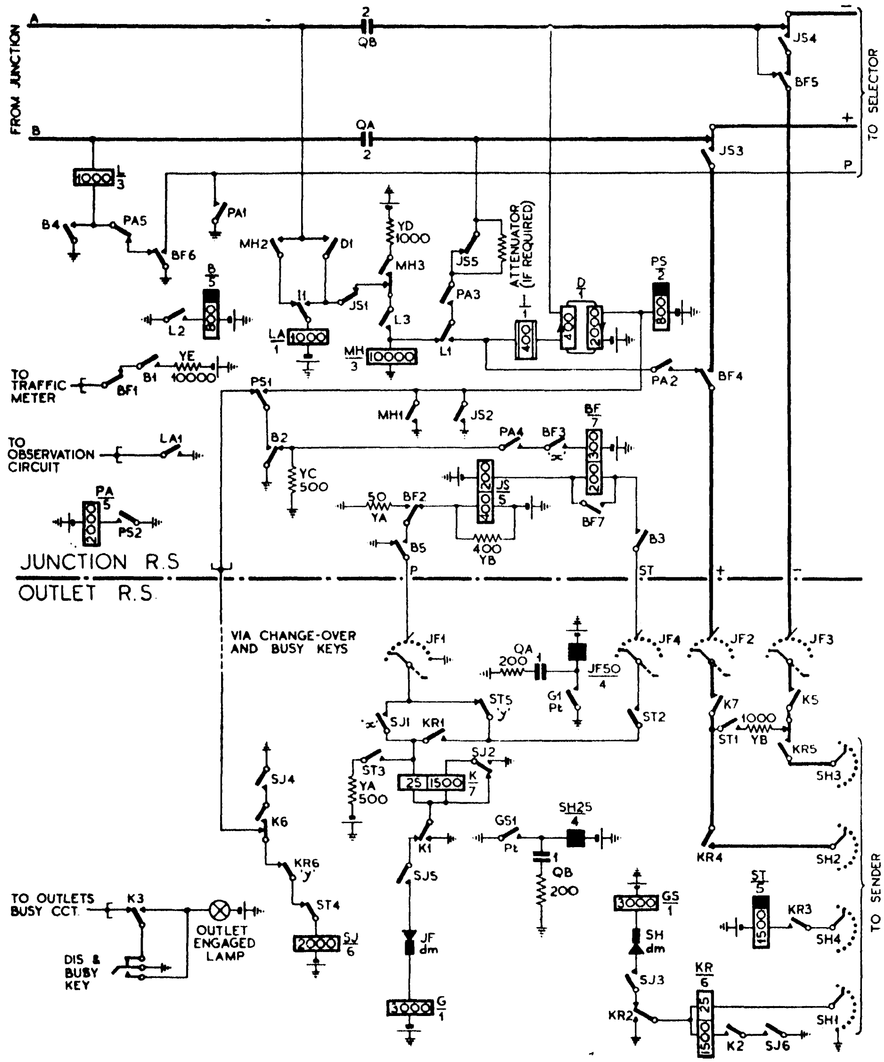


Fig. 534. Junction Relay Set and Outlet Relay Set

extended from the sender to operate relay *ST*. ***ST*1** provides a holding loop for the forward apparatus to cover the period between the termination of pulsing out and the release of relays *K* and *JS*. ***ST*2** operates relay *BF* and holds relay *JS* over the same circuit. ***ST*3** similarly provides a temporary holding circuit for relay *K* to guard against false release which might occur during the transfer of its holding circuit to the *ST*-wire (due the 1st selector. At the completion of pulsing out, *KR* is released from the sender, but the release of *ST* is deferred for a period to provide an alternative holding loop until *JS* releases.

Sender. The connexions of a 4-digit sender circuit are shown in Fig. 535. The operation of relay *KR* in the outlet relay set provides a low resistance earth on the *P*-wire which operates relay *BG* in the sender. The contacts of *BG*

prepare various holding circuits, start up the impulse machine, and operate the traffic recorder. ***BG*6** extends the battery connected *GP* relay to the *P*-wire of the position or V.F. relay set hunter and, if the wipers of this switch are standing on an engaged outlet, *GP* operates to the earth condition and ***GP*1** energizes the driving magnet of the hunter uniselector. Relay *GP* and the *PHdm* contacts interact to step the uniselector until an outlet to a free position (or V.F. relay set) is encountered. Relay *K* now operates to the battery on the free outlet, and at ***K*1** disconnects *GP* to stop the drive. ***K*1** also applies a low resistance earth to guard the outlet against intrusion. ***K*3** steps the digit distributor off-normal to prevent a lock-up of relay *BG* should the sender be first seized and then released. ***K*4** operates relay *KA* which, at ***KA*1** and ***KA*7**, extends the *D* and *I* loop of the junction relay set to the V.F. relay set or B-position. Contacts ***KA*2** to ***KA*5** extend the *W*-, *X*-, *Y*-, *Z*-, and *C*-wires to the digit distributor wipers, whilst ***KA*6** prepares the *C*-wire circuit in readiness for the cancel or release signals.

In the V.F. keysending system, it is necessary to send out an initial "cancel" signal to restore any relays which may have operated due to surges when the V.F. relay set is seized. This cancel signal is received in the V.F. relay set, and is arranged to apply a 1200 Ω earth on the *C*-wire. Relay *CK* operates to this earth and at ***CK*2** releases the storage relays. The same sequence of circuit operations also occurs if the sender is used in conjunction with the keysender B-position. In this case, however, the cancel key is not depressed automatically before keying, but is used only when the operator wishes to cancel any digits which have been incorrectly keyed.

The V.F. signals from the distant exchange are received in the V.F. relay set (or oral instructions are passed to the B-position operator). These signals are passed forward to the sender in the form of earth combinations on the *W*-, *X*-, *Y*-, and *Z*-wires. After the first earth signal, relay *DS* operates in series with the appropriate storage relays, and *DS*1 causes the digit distributor to step at the cessation of the earth pulse. Relay *SS* operates when the complete number has been stored, and at ***SS*2** disconnects relay *KA* to release the V.F. or position equipment. ***SS*2** also connects earth to relay *IG* to initiate the sending out of Strowger impulses. ***SS*3** applies an earth to the *ST*-wire to operate the *ST* relay in the outlet relay set. Relay *IG* operates at the first break of the impulse machine magnet springs, and ***IG*2** completes the circuit for the send switch driving magnet. Relay *SA* operates when the send switch reaches position 3, and at ***SA*1** removes the short circuit from the line impulse springs. ***SA*3** energizes the control switch magnet to allow it to step at the end of each train of impulses. Relay *SZ* operates when the send switch wipers reach the contact marked by the first digit storage relays, and at ***SZ*1** short-circuits the line impulse springs. ***SZ*2** releases relay *IG* and disconnects the sender switch driving magnet circuit. The restoration of *IG*1 completes a self-drive circuit for the send switch until the wipers reach contact No. 14. The ***S*1** earth is extended via ***SZ*3** to operate relay *IG*. The send switch now drives under the control of the magnet springs until contact No. 18 is reached. This stepping period gives the required inter-digital pause. The send switch now drives under self-interruption from contact 18 to its home position. When the switch is normal, relay *SA* releases, and at *SA*2 releases *SZ*. The release of *SA*3 causes the control uniselector to make one step. Each of the remaining three impulse trains is transmitted in exactly the same way but, at the end of the units train, a circuit is completed for relay *CO* which, at ***CO*2**, removes the earth from the *ST*-wire. Relay *ST* in the outlet relay set now releases to provide a holding loop for the train of selectors. ***CO*3** disconnects relay *BG* and releases relay *KR* in the outlet relay set. At the same time it applies an earth to the *P*-wire to guard the circuit against intrusion during the release period. All the uniselectors now home, but relay *BP*, which is in series with the magnets, is held during the homing time. ***BP*1** holds relay *CO*, and ***BP*2** extends the *A* relay to the *S* pulse of the release alarm circuit. If relay *A* is still held at the end of the 30 sec delay period, relay *B* operates to set up alarm conditions and to flash the supervisory lamp.

Keysender B-position Circuit. Fig. 536 shows the connexions of the equipment on a keysender B-position. Relay *PR* operates over the transmitter circuit when a telephone instrument is inserted into the position jack. ***PR*1** disconnects the earth from the incoming *P*-wire to open up the position for traffic. When an incoming call is routed to the position, relay *LR* operates from earth applied from the sender over the *P*-wire. ***LR*1** lights the position pilot lamp, whilst ***LR*2** and ***LR*3** apply earth to the digit keys, etc., in readiness for keying. Relay *LO* also operates to the loop extended from the junction relay set, and ***LO*1** extends the 400 c/s tone to the negative wire. ***LO*2** operates relay *TA*. ***TA*1** disconnects the tone from the negative wire, whilst ***TA*2** completes a circuit for *TB*. ***TB*2** operates relay *TC*. At the same time, ***TB*3** re-applies the 400 c/s tone to the negative wire. After a further short operating lag, *TC*

operates. *TC3* disconnects the tone to line and this contact, in conjunction with *TC2*, extends the incoming loop to the operator's telephone circuit. *TC4* disconnects relays *TA* and *TB* and provides a separate holding circuit for the *TC* relay under the control of *LO*.

The circuit is now established for the B-position operator to receive a demand from the distant A-operator. After receiving the number required, the operator proceeds to key up the digits on the position digit keystrip. The operation of any digit key completes a circuit for relay *M*, which locks

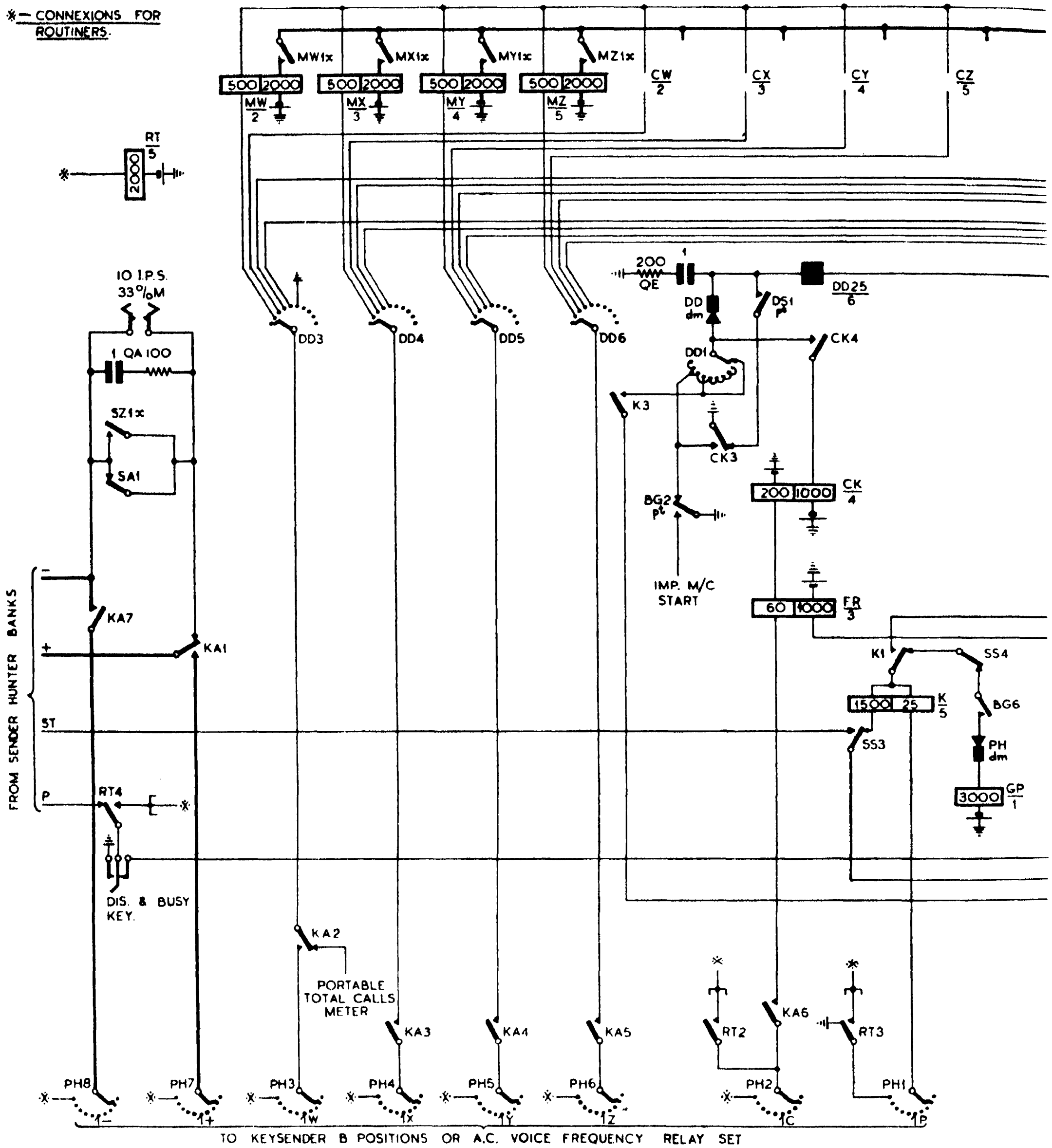
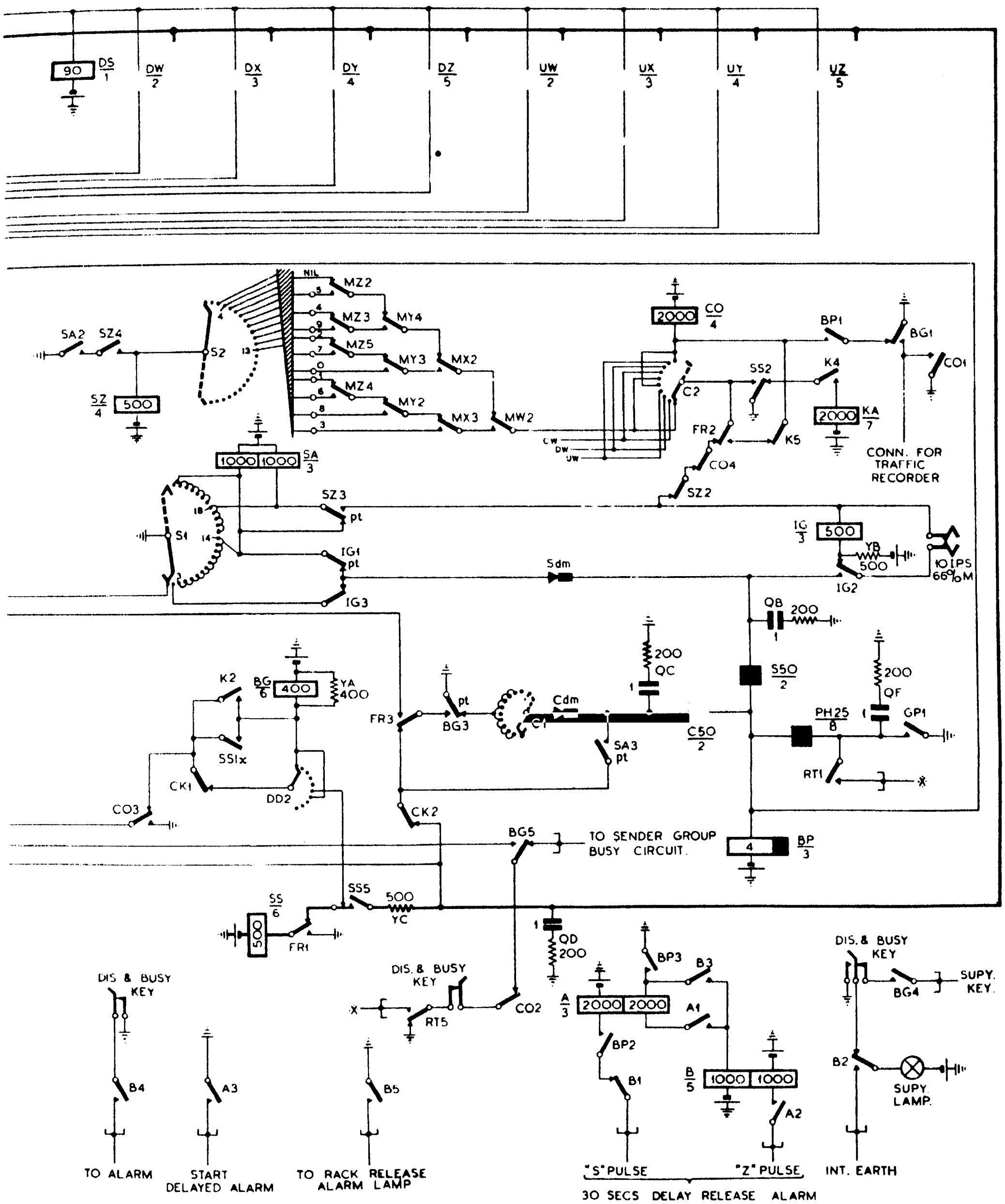


FIG. 535. 4-DIGIT

at *M1* under the control of the cancel key or of *LR3*. *M2* operates the total calls meter, whilst *M3* introduces resistor *YB* into the operator's receiver circuit to prevent clicks. A cancel key is provided so that the operator may cancel any number which may have been incorrectly set up.

This signal is passed to the sender by the application of a 1200 Ω earth on the *C*-wire. A release key is also provided to enable the operator to release the position circuit should the position be seized and no number demanded. The release condition is a full earth on the *C*-wire, and the sender



SENDER

circuit is arranged to differentiate between the two conditions.

After completion of keying, the loop is removed from the negative and positive wires to release *LO* in the position circuit. *LO*3 releases *LR*, and the position circuit is restored to normal in readiness for the next incoming call.

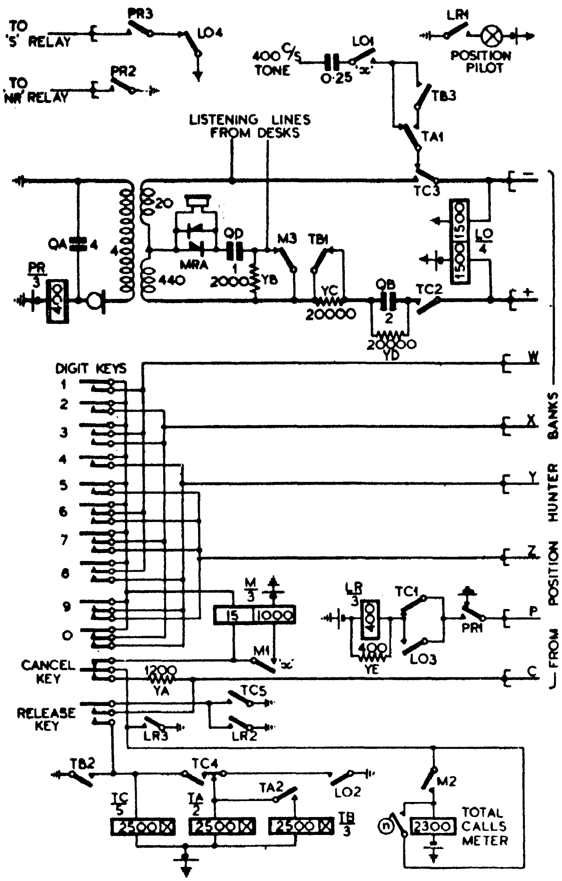


FIG. 536. KEYSENDER B-POSITION CIRCUIT

Contact *LO*4, in conjunction with *PR*3, provides for the removal of earth from the position busy common during the time when a position is staffed and a call is in progress.

Voice-frequency Relay Set. Fig. 537 shows the connexions of the voice-frequency relay set designed for use in conjunction with 4-digit key-sending from A-positions. The voice-frequency signal currents are detected by four mechanically tuned relays *W*, *X*, *Y*, and *Z*. These relays are of special construction and have been described in Vol. I. Essentially the voice-frequency relay consists of a powerful permanent magnet with the line coils mounted on the pole-pieces. The moving system consists of a balanced armature, which is rigidly connected to a reed, the natural frequency of which is adjustable. The reed carries a small loop spring at its free extremity, and a contact weight is located between this loop spring and a similar spring fixed to the frame of the relay. Ordinarily there is good electrical contact between the weight and the loop springs, but, if the line coils are excited by current of the frequency to which the reed is tuned, vibration of the latter produces intermittent disconnexions of the circuit via the loop springs. The relay is comparatively insensitive to line currents of other frequencies. The voice-frequency relay contacts are placed in parallel with a relief relay, so that energization of the V.F. relay allows the relief relay to operate.

A battery testing circuit is employed between the sender and the V.F. relay set (i.e. the free condition of the V.F. relay set is indicated by battery via relay *LR* on the *P*-wire). When the sender is seized for an incoming call, the V.F. relay set hunter automatically drives until a free V.F. relay set is encountered. Relay *K* in the sender (see Fig. 535) now operates, and applies a low resistance earth to the P-wire to guard the V.F. relay set. Relay *LR* (Fig. 537) now operates, and at ***LR*1** prepares the holding circuit for the V.F. relief relays, etc. The extension of the — and + wires to the V.F. relay set now operates relay *LO* and the battery returned over the + wire from this relay darkens the supervisory lamp at the originating exchange. Contact ***LO*1** connects a 400 c/s tone to line. At the same time ***LO*3** completes a circuit for the slow-to-operate relay *TA*. After a short period of lag, ***TA*2** completes a circuit for a similar relay *TB*. After a further short period of lag, *TB* operates, and ***TB*1** completes the circuit of *TC*, which is also slow-to-operate. ***TC*5** now disconnects the holding circuit for relays *TA* and *TB*, and at the same time provides a holding circuit for relay *TC* until such time as *LO* restores when the V.F. relay set is released.

The first operation of contact ***TA*1** disconnects the 400 c/s tone, but shortly afterwards the operation of ***TB*2** re-applies this tone until such time as ***TC*2** changes over. The distant manual exchange operator therefore receives two short pips of 400 c/s tone to indicate that the equipment is ready for the transmission of the V.F. signalling currents. The A-operator now depresses the start key and then proceeds with the keying up of the four numerical digits of the required subscriber's number. The depression of the start key causes the *W*, *X*, and *Z* frequencies to be sent to line, thereby operating relays *W*, *X*, and *Z* of the voice-frequency relay set. The vibration of contacts *W*1, *X*1, and *Z*1 allows the relief relays

WA, *XA*, and *ZA* to operate. The circuit arrangements are such that, when these three relays are operated simultaneously, a short circuit is removed from relay *CR*, and the latter operates. **CR1** in such cases allows the first *S* pulse to operate relay *TP*. The subsequent *Z* pulse applies full earth to the *C*-wire to initiate forcible release of the V.F. relay set.

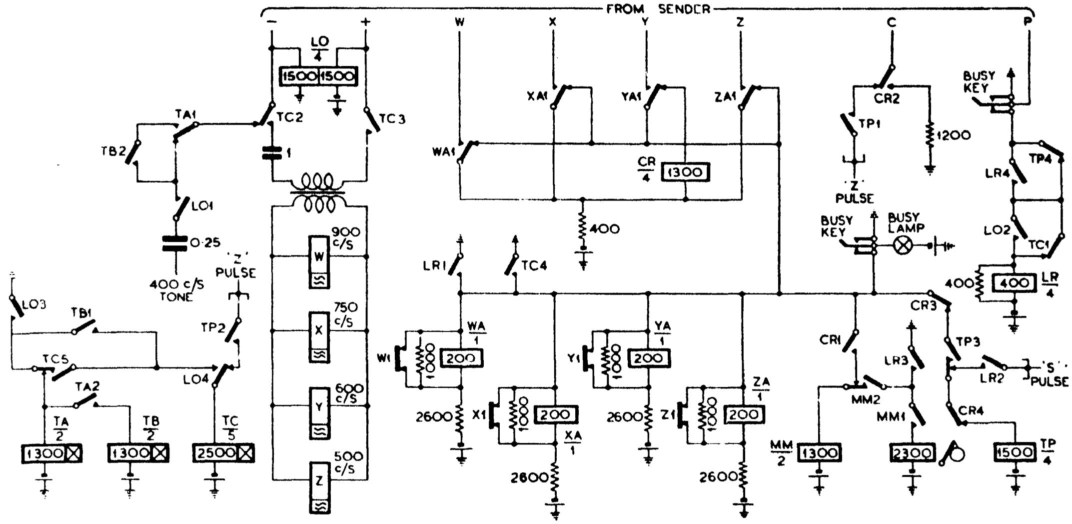


Fig. 537. Circuit of Voice-frequency Relay Set

operates relay *MM*, whilst **CR2** connects earth via the 1200 Ω resistor to the *C*-wire of the sender. Relay *CK* in the sender circuit (Fig. 535) now operates, and in turn causes the digit distributor to step to the contacts associated with the first (thousands) group of storage relays. Other contacts of the *CK* relay release any storage relays which may have been prematurely operated. The cessation of the start signal allows relays *WA*, *XA*, and *ZA* to restore, and the replacement of the short circuit across relay *CR* and the consequent removal of the 1200 Ω earth from the *C*-wire completes the preparation of the sender circuit for the reception of the thousands digit.

The keying of the thousands, hundreds, tens, and units digits operates in turn various combinations of the *WA*, *XA*, *YA*, and *ZA* relays, and the contacts of these relays are arranged to apply combination earth signals to the *W*-, *X*-, *Y*-, and *Z*-wires of the sender. These earth signals in turn operate storage relays in the sender. At the end of each marking condition, the removal of the earth from the V.F. relay set allows the digit distributor in the sender to make one step, thereby connecting the next group of storage relays to the *W*-, *X*-, *Y*-, and *Z*-wires.

The V.F. relay set is provided with a time pulse release, so that the circuit is forcibly disconnected if the start signal does not follow within a period of 30 to 60 sec. The non-operation of contact *CR4*

Should the A-operator desire to cancel a partial key-up, the operation of the start and cancel key at any time prior to the keying of the units digit re-operates relay *CR*, and contact **CR2**, by applying a 1200 Ω earth to the *C*-wire, releases any operated

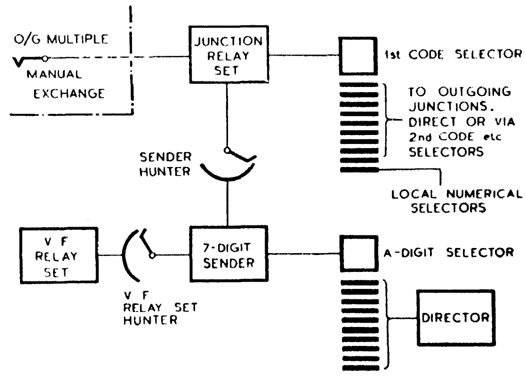


Fig. 538. Trunking Arrangements of 7-digit Keysender Scheme

storage relays in the sender. Should the units digit have been sent, however, the sender will have commenced pulsing out, and the cancellation can then be effected only by removing the plug from the junction jack and re-establishing the call.

7-digit Keysending. In a director area there are many occasions when the traffic between a manual exchange and a particular automatic exchange is

insufficient to justify a direct junction route worked on a 4-digit keysending basis. A 7-digit keysending scheme has been designed for use in these circumstances. In this scheme (Fig. 538) a junction is terminated on a relay set, with which is associated a sender hunter and a 1st code selector. The receipt of a calling signal causes the sender hunter to search for and switch to a disengaged

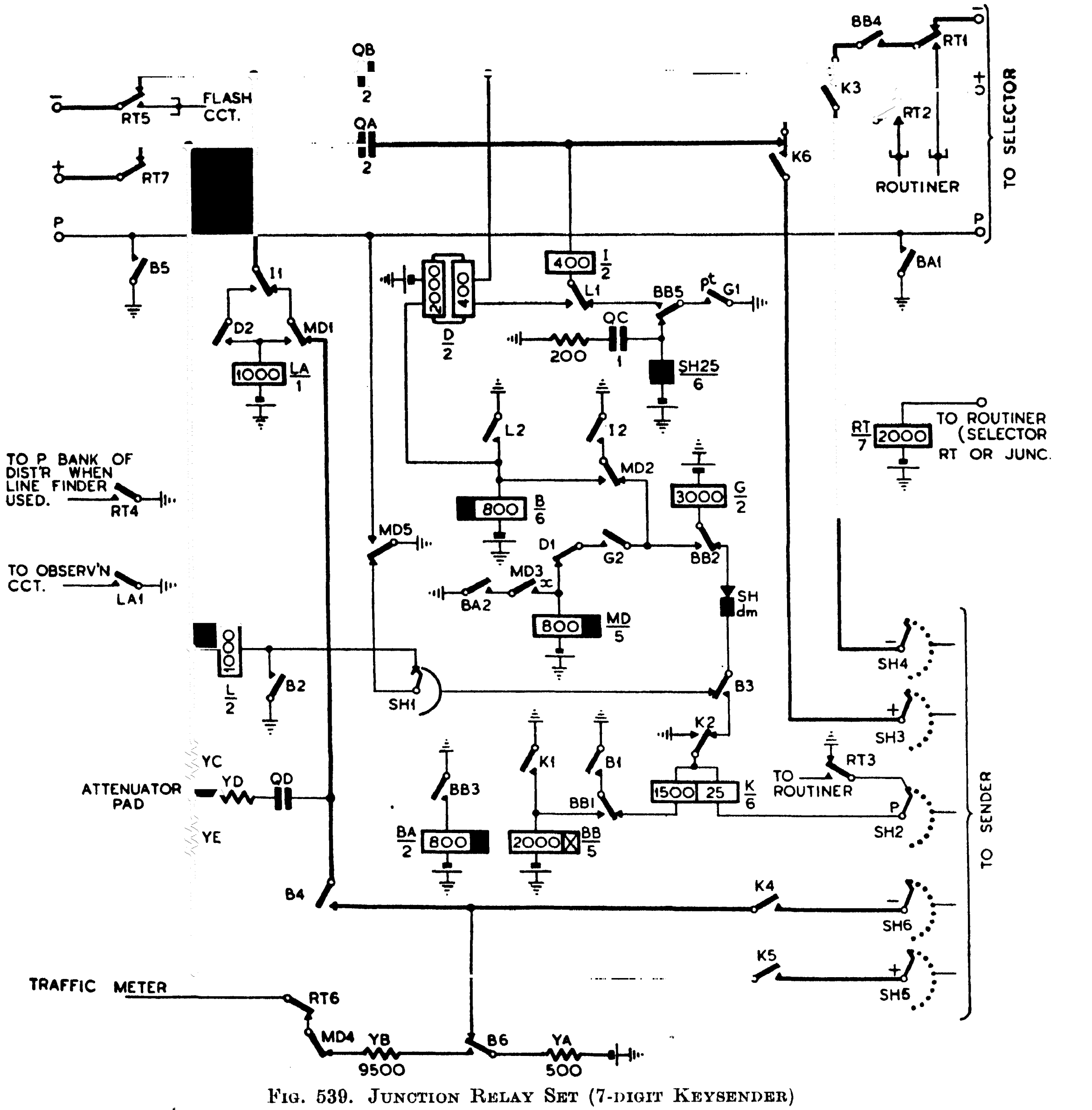


Fig. 539. Junction Relay Set (7-digit Keysender)

route is provided from the manual exchange to a nearby automatic exchange, and the director equipment at the latter is utilized to route the call to the required exchange.

The A-operator at the manual exchange plugs into the multiple jack of an outgoing junction on the 7-digit route. At the automatic exchange each 7-digit sender. The seizure of the sender in turn causes a V.F. relay set hunter to search for and switch to a free voice-frequency relay set. The voice-frequency relay sets used in 7-digit keysending are identical to the relay sets used for 4-digit keysending, and it is in fact quite usual to use a common group of relay sets to serve

both the 4-digit and the 7-digit senders in the exchange.

As soon as the V.F. relay set is ready to receive the signals from the manual exchange, a pip-pip tone is returned over the junction to the A-operator, and the supervisory lamp associated with the calling cord is darkened as an indication that keying may proceed. The A-operator now depresses the start and cancel key as in the 4-digit system, and then proceeds to key-up first the exchange code and then the 4 numerical digits. The coded voice-frequency signals are detected in the V.F. relay set, and appropriately coded d.c. signals are returned to the sender where the digits are stored on a series of relays. On completion of keying, the V.F. relay set is released.

Each 7-digit sender has an A-digit selector associated with it. These A-digit selectors are fitted on the same racks as the normal A-digit selectors of the director exchange, and thus have access to the ordinary directors. The impulse trains are transmitted from the sender in the form of Strowger impulses to step first the A-digit selector and then the *BC* switch and storage uniselectors of the director. The pulsing-out circuit of the director is routed through the sender, and the junction relay set, to the 1st code selector associated with the latter. At the appropriate time the director pulses out the correct translation to step the code selectors, tandem selectors, etc., to route the call to the required exchange. The 4 numerical digits are then transmitted and, when pulsing out is completed, the sender is released for use on further calls. The transmission bridge and the holding circuit for the local train of selectors are provided by the incoming junction relay set. Hence it is possible to utilize switches of the ordinary group selector type (i.e. without transmission bridge) for the 1st code selectors on 7-digit keysender calls.

In general, the outlets from the 1st code levels are commoned to the outlets from the subscribers' 1st code selector levels. Thus the keysender traffic is combined with the normal subscribers' traffic on the various outgoing junction routes. In certain cases it is necessary, in order to meet transmission requirements, to provide a higher grade of junction to the tandem or sub-tandem exchange for the 7-digit traffic. In such cases the keysender 1st code tandem levels are segregated from the normal tandem levels and are given access to a separate group of higher grade junctions.

Junction Relay Set and 7-digit Sender. Fig. 539 shows a typical circuit of an incoming relay set on a 7-digit keysending system. Apart from the use of a sender hunter individual to each junction relay set, the facilities provided are substantially similar to those of Fig. 534 and it should be readily possible to understand the circuit operation from the description already given.

The 7-digit sender circuit follows the same

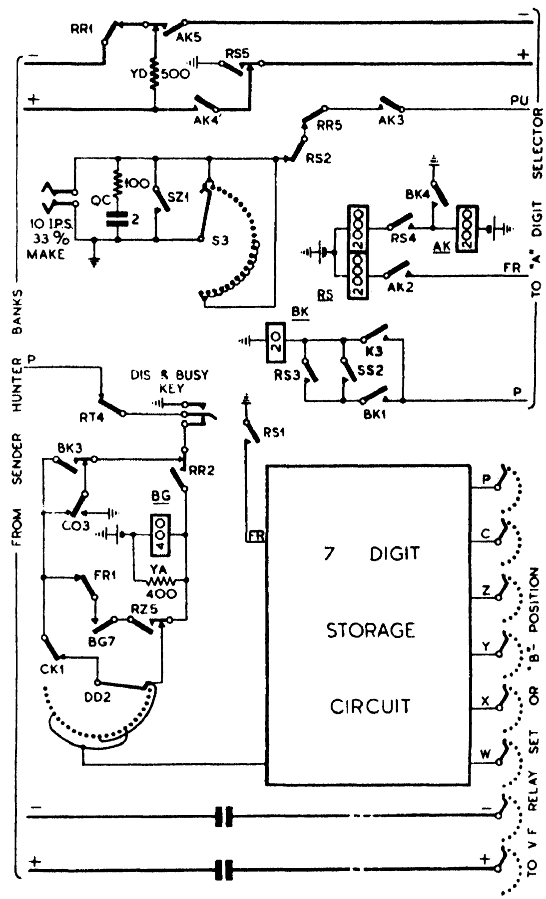


FIG. 540. PULSING-OUT ELEMENT OF 7-DIGIT SENDER

general lines as the 4-digit sender shown in Fig. 535, and a separate illustration of the complete circuit is not necessary. The main difference is the provision of 7 groups, each of 4 relays, for the storage of the d.c. signals from the V.F. relay set. (Only 4 such groups are required in the 4-digit sender.)

The condition of the storage relays is used to mark the banks of a sender switch, which in turn controls the outgoing Strowger impulses. Whereas in the 4-digit sender the impulses are passed back via the sender hunter, in the 7-digit scheme the

impulses are routed direct to an A-digit selector associated with the sender.

Fig. 540 shows the pulsing-out element of the 7-digit sender. Relay *BG* is operated by the earth on the *P*-wire when the sender is seized by the sender hunter. The contacts of this relay (not shown) prepare the circuit for the sender storage relays and cause the V.F. relay set hunter to search for and seize a free voice-frequency relay set. When the sender switches to a free voice-frequency relay set, relay *K* operates to extend the signal leads to the storage relays, and at ***K*3** applies relay *BK* to the *P*-wire of the A-digit selector. Relay *BK* now operates in series with the pre-operate winding of the *A* relay in the A-digit selector. *BK* prepares the pulsing-out circuit of the sender, and at ***BK*4** operates relay *AK*. ***AK*3** extends earth over the *PU*-wire to hold the A-digit selector, whilst ***AK*4** and ***AK*5** extend the — and + wires in readiness for the subsequent pulsing out from the director.

When all 7 digits have been received and stored in the sender, relay *SS* (not shown) operates and at ***SS*2** completes a holding circuit for relay *BK* in readiness for the release of relay *K* when the V.F. relay set is released. The circuit is now ready for the transmission of the stored digits, and the send switch is driven at 10 I.P.S. until it reaches the contact marked by the first set of storage relays. At the third step, the *S*3 wiper removes the short circuit from the impulse springs, and allows earth impulses to be transmitted to the A-digit selector over the *PU*-wire. When the send switch encounters the marked contact, relay *SZ* operates, and at ***SZ*1** re-applies a short circuit across the impulse springs. The send switch now homes. All 7 digits are sent out in this manner, and at the completion of pulsing out relay *CO* is operated. ***CO*3** prepares to return earth on the *P*-wire at a later stage when *BK*3 restores on the release of the A-digit selector and director.

When the director has completed sending, the disconnexion of the battery on the *P*-wire allows *BK* to release, and *BK*3 in turn allows *BG* to restore. *BK*4 also releases *AK*, and *AK*5 connects a 500 Ω loop across the + and — wires to hold the 1st code selector and subsequent switches until such time as the junction relay set switches the junction directly through to the selector. The release of *BG* allows the various switches, etc., in the sender to restore.

Relay *RR* operates should the telephonist release the call after a V.F. relay set has been seized. ***RR*1** and ***RR*5** release the A-digit selector and the 1st code selector. Forced release conditions, due to prolonged holding of the V.F. relay set, cause the operation of relays *CK* and *FR*. *CK* allows the various mechanisms in the sender to release, whilst ***FR*1** releases relay *BG* and the switching relay of the junction relay set. If forced release conditions are returned from the director, the opening of the pulsing-out loop releases the 1st code selector and any succeeding switches, whilst the application of an earth on the *FR*-wire operates relay *RS*. ***RS*1** applies forced release conditions to the sender, whilst ***RS*2** disconnects the earth on the *PU*-wire to release the *A* relay of the director. ***RS*3** holds relay *BK* until such time as the battery is removed from the *P*-wire by the director. ***RS*4** provides a hold circuit for *RS* independent of the condition on the *FR*-wire until *BK* restores to normal when the director is fully released. Similarly, if all outlets from the A-digit selector to the directors are engaged, the return of a busy signal on the *FR*-wire operates relay *RS* and the above release cycle follows.

EXERCISES XVII

1. A certain B-position at a manual exchange of the C.B. type is required to complete incoming calls from a number of manual exchanges and also from a nearby automatic exchange. It is desired to retain key supervision on calls incoming from manual exchanges, but to provide automatic metering on incoming calls from the adjacent automatic system. Show by means of suitable circuit elements how these facilities can be provided.

2. What are the advantages and disadvantages of using only one wire of a junction line for dialling from a manual exchange to an automatic exchange? Give a diagram and a description of a relay set which:

(*a*) receives battery impulses and converts them into loop impulses,

(*b*) returns a signal to the manual exchange when the called subscriber answers,

(*c*) returns a "busy" signal if engaged conditions are encountered.

(*C. & G. Telephone Exchange Systems II*, 1947.)

3. Enumerate the facilities afforded by the relay set provided at the main automatic exchange in a non-director area on trunk demand circuits outgoing to a distant automanual switchboard.

Explain, with the aid of a diagram of the circuit elements concerned at both ends of a junction, how "manual hold" . . . facilities are given on calls from (*a*) main exchange subscribers' selector levels, (*b*) satellite selector levels at the main exchange. Assume that the automanual board is equipped for sleeve control working. (*C. & G. Telephony, Grade III*, 1942.)

4. Give a diagram of an incoming termination suitable for use on the junctions from a U.A.X. to its parent switchboard, which is of the sleeve control type. Explain concisely how the circuit discriminates between calls which originate from ordinary subscribers and from coin-box users.

5. In the case of a call from a director exchange to a manual exchange equipped with coded call indicator apparatus, a relay set causes the coder hunter to search for a free coder. Describe, with reference to a circuit diagram, the operation of this relay set during the progress of a call. (*C. & G. Telephony, Grade III*, 1942.)

6. Draw a schematic diagram of the coded call indicator system to show the relative circuit positions of the various assemblies of relays and uniselectors involved in the completion of a call. Describe briefly the basic functions of each of the following components:

(*a*) Decoding control switch.
(*b*) C.C.I. relay set.
(*c*) C.C.I. coder.
(*d*) Marker.
(*e*) Position trunk relay set.

(*C. & G. Telephony, Grade III*, 1946.)

7. In the coded call indicator system the coded pulses for the digit 3 are described as light positive, heavy negative and light negative. Describe the manner in which these pulses are produced at a director exchange and how they are received and stored at the manual exchange. Illustrate your answer with a simplified circuit diagram. (*C. & G. Telephony, Grade II*, 1944.)

8. Describe the arrangements which are made, in the coded call indicator system, to ensure a measure of uniformity in the loading of operators' positions, and give sketches of the circuit elements concerned. (*C. & G. Telephony, Grade III*, 1947.)

9. Describe with the help of suitable sketches how the sender circuit provides for the transmission of loop-disconnect impulse trains on receipt of 4-wire combination signals from a voice-frequency relay set. What happens if an irregular combination is received from the V.F. relay set?

10. Describe a system of keysending in which currents of four voice-frequencies are employed. Give a diagram of circuit elements only, to illustrate the essential features of the system. State the advantages of such a system as compared with a direct current system of keysending. (*C. & G. Telephone Exchange Systems II*, 1948.)

CHAPTER XVIII

OTHER STEP-BY-STEP AUTOMATIC SYSTEMS

We have seen that the current standard automatic system in Great Britain is essentially a step-by-step system based on the use of 2-motion selectors. Various telephone administrations have utilized these same principles in the development of systems which are essentially similar, but which differ in detail from the British scheme. It is not possible in the space available in this volume to consider all the many actual and possible variations of step-by-step switching systems, except in so far as they affect the telephone system of this country.

The No. 16 system designed by Messrs. Siemens Brothers in the early days of automatic telephony, and which is still in service in a number of large towns and cities, is, however, of special interest and a brief description is given in this chapter. The latter part of the chapter discusses the possibility of obtaining economies by the use of common controlling relays in a Strowger system.

SIEMENS NO. 16 SYSTEM

The Siemens No. 16 system was installed, and is still in use, at a number of the older automatic exchanges in Great Britain (notably Edinburgh, Sheffield, Brighton, and Leicester). It is a step-by-step system and is in many respects similar to the standard system described in this volume. Many of its features have in fact been retained in the design of modern automatic switching equipment. The Siemens No. 16 system employs subscribers' preselectors (uniselectors) and 100-point 2-motion selectors, and is designed to operate on a 60 V supply. The trunking between the subscribers' lines and the 1st group selectors makes use of two stages of preselection by means of 10-outlet unidirectional mechanisms. A feature of the system is the location of the transmission bridge in the 1st group selector and the consequent repetition of impulses by the 1st selector to the succeeding selectors in the train. Battery impulsing over the *B*-wire is used for the repeated impulse trains. The subscriber's telephone and dial are of the standard type, as also are the tones provided.

The hunting drive for the various selectors is provided by the interrupter spring sets of an impulse machine (*motor interrupters*). These spring sets provide impulses at the rate of 34 per second for uniselectors and group selectors, and at 17 per second for the automatic hunt over P.B.X. groups. The use of machine impulses instead of the self-interrupted drive of the present standard system is one of the main distinguishing features of a Siemens No. 16 exchange. Plant economies make it necessary to utilize each set of machine impulse springs for a number of selectors. This in turn introduces a theoretical liability that two selectors may be hunting simultaneously over the same level, and may seize the same free trunk. In practice, however, the individual variations in the characteristics of the different selector circuits are such as

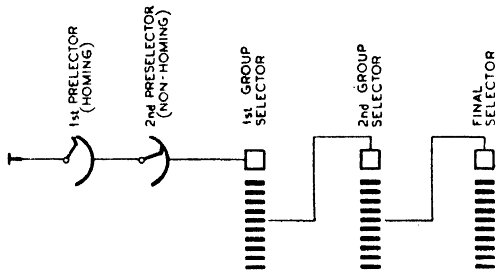


Fig. 541. General Trunking Scheme of Siemens No. 16 System

to reduce materially this possibility of dual connexions. Moreover, a guard against simultaneous switching is provided by the use of battery testing circuits which are designed to minimize the chance of two testing relays switching simultaneously to the same outlet.

Trunking. The general trunking arrangements of a non-director exchange are shown in Fig. 541. Apart from the use of 1st and 2nd subscribers' uniselectors, the arrangements are identical to those of the Post Office present standard system.

The method of interconnecting the 1st and 2nd preselectors is interesting. The 1st preselectors are arranged in groups, so that each group carries—as nearly as possible—an equal volume of traffic. The preselectors of one group are trunked via 2nd preselectors to a maximum of 100 1st selectors. The 1st preselectors, the 2nd preselectors, and the group of 100 (maximum) selectors are known as a *division*.

The bank multiples of the 1st preselectors of a division are divided into 20 sub-groups or "rows," each row being designated by a letter (Fig. 542). The 2nd preselectors of the division are arranged in 10 sub-groups (or rows) each of 20 switches.

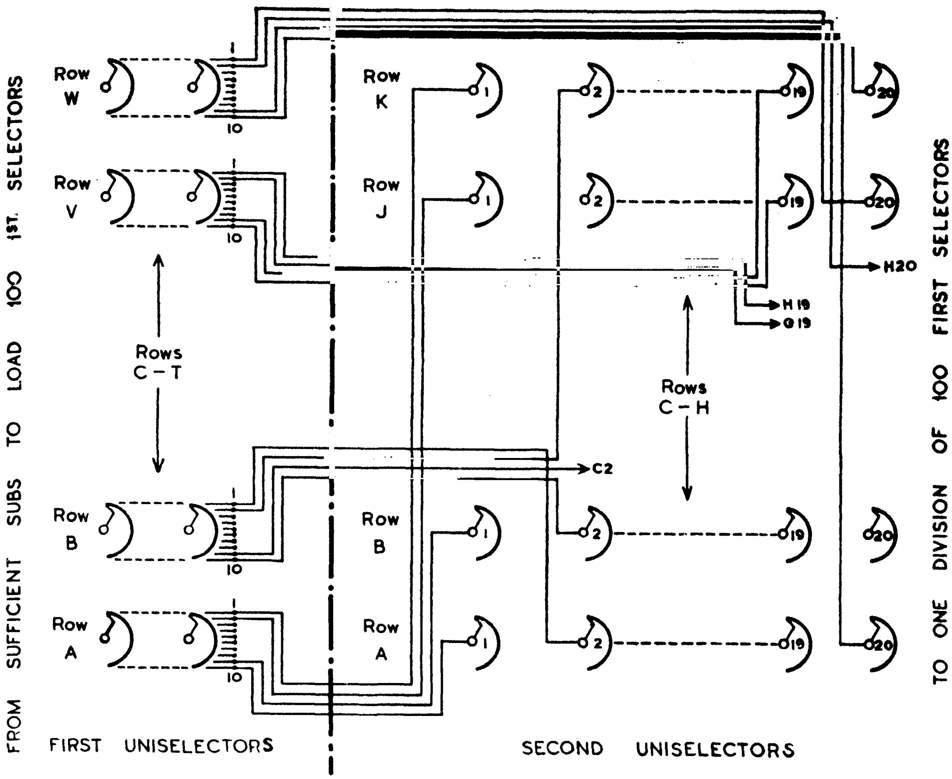


FIG. 542. INTERCONNEXION OF 1ST AND 2ND PRESELECTORS (UNISELECTORS)

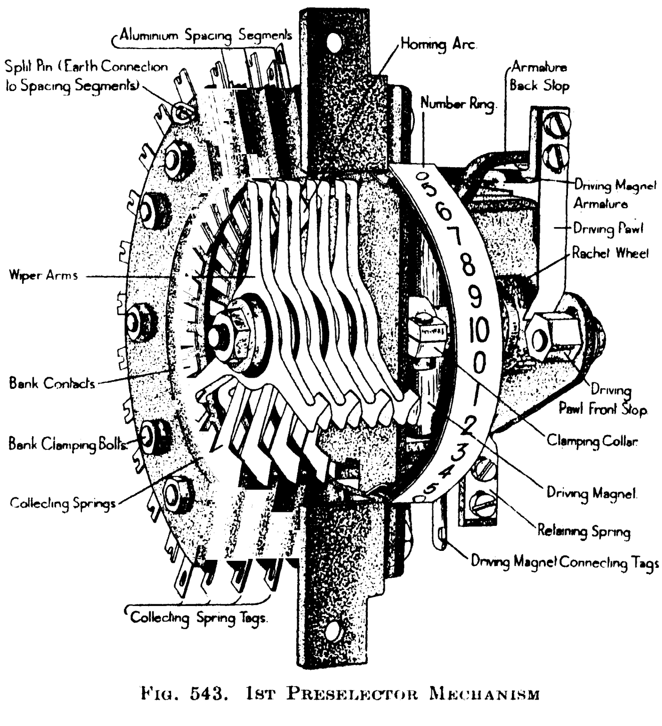


FIG. 543. 1ST PRESELECTOR MECHANISM

The 2nd preselectors are of the 10-outlet non-homing type, and the 10 outlets from each row of 2nd preselectors are trunked to 1st selectors. The 1st and 2nd preselectors are so interconnected that the traffic from any one row of 1st preselectors is spread over all the sub-groups of 2nd preselectors. Thus, each switch in the common pool of 100 1st selectors serving the division is accessible from every individual subscriber's 1st preselector. In effect, full availability conditions exist within each division of 1st selectors provided that there is no congestion at the 2nd preselector stage.

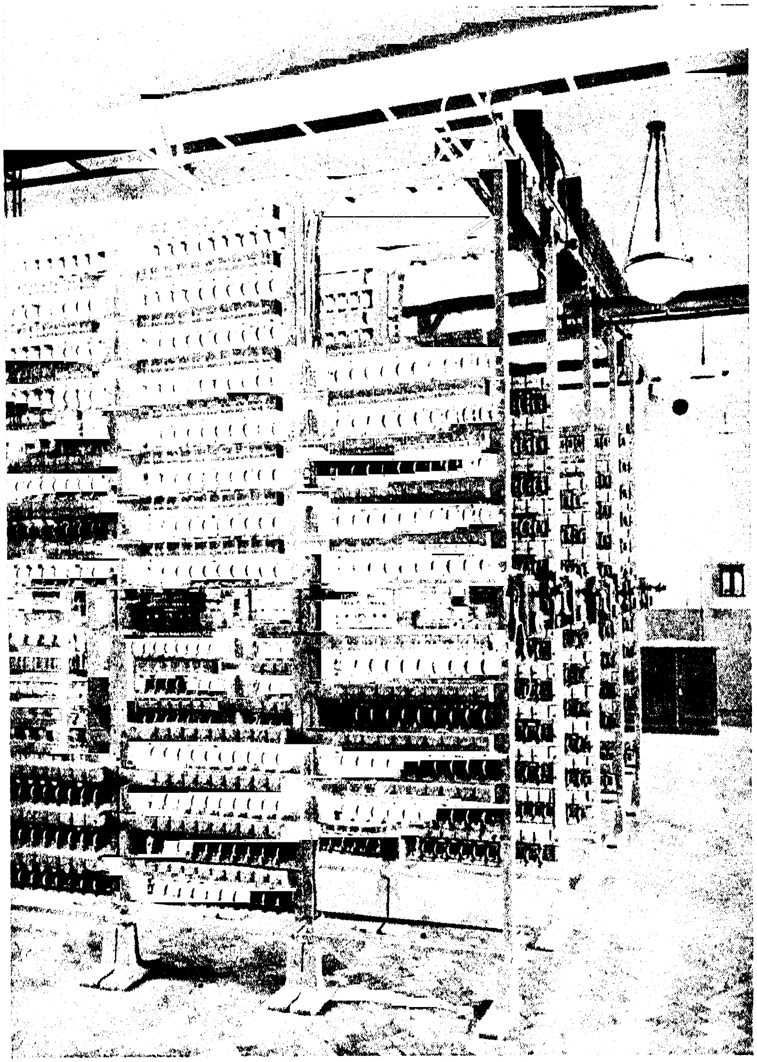


FIG. 544. TYPICAL PRESELECTOR RACKS—SIEMENS 16 EXCHANGE

Preselector Mechanism. A subscriber's uniselector (known generally in the Siemens No. 16 system as a 1st preselector) is illustrated in Fig. 543. The wiper assembly is provided with 4 sets of bronze wipers, each wiper consisting of 3 arms spaced at 120° to each other. One or other of the 3 arms is always outside the bank and acts as a pointer to indicate the number of the bank contact on which wipers are standing. The bank is made up of 4 arcs, to provide the speaking pair, the control or C-wire, and the homing arc. Aluminium spacing strips are provided between the contacts of each arc to provide the necessary spacing and to act as electrostatic screens.

The mechanism is of the forward-acting type, i.e. the wipers are stepped forward on the operation of

the driving magnet. Generally speaking, forward acting uniselectors of this type are less satisfactory than reverse-acting mechanisms, and there is a danger, if the switch is not in good adjustment, of the wipers resting between contacts should the magnet receive a clipped impulse from the machine interrupters.

The secondary preselectors are of the non-homing type with 3 arcs, but they are otherwise substantially similar to the subscribers' preselectors.

The preselectors are mounted on racks (Fig. 544), each rack accommodating 10 rows of 10 preselectors together with their associated relay groups.

2-motion Selector Mechanism. The mechanism of the group and final selectors is very similar to that of the standard pre-2000 type switch described in Chapter III. The shaft of the selector (Fig. 545) carries three pairs of bronze wipers. The upper wipers provide a connexion to the *C*-wire of the required outlet. (The *C*-wire of a Siemens No. 16 exchange is the same as the *P*-wire of the standard system.) The two lower pairs of wipers are connected in parallel to form two sets of line wipers. The spacing between the levels in the two lower banks is double that between the levels in the *C* bank. The first five levels from the bottom are the odd-numbered line contact levels (*A* and *B* levels), whilst the even-numbered levels are accommodated on the centre section of the bank assembly. When the shaft is stepped vertically in response to an even-numbered digit, the upper pair of line wipers enters an even level, whilst the lower pair rotates between two odd levels. Similarly, when the shaft is stepped to an odd-numbered digit, the upper wipers rotate between two even levels, whilst the lower pair enters an odd level. This arrangement results in the bank being spread out, so enabling normal cable forms to be used for the wiring of the selector bank multiple. The bank wiring of the Siemens 16 2-motion selector is much more accessible than that of the standard selector. The usual 11th bank contact in each level is provided to give busy conditions when all the trunks on the level are engaged.

Group selectors are provided with vertical off-normal springs (termed *K* contacts), whilst final selectors have rotary off-normal springs (termed *W* contacts) in addition to the *K* contacts. The relays associated with the 2-motion selectors are dissociated from the selector plate and are mounted on a separate jacked-in relay set which is normally placed immediately above the selector mechanism with which it is associated. Fig. 546 shows part of a typical final selector rack.

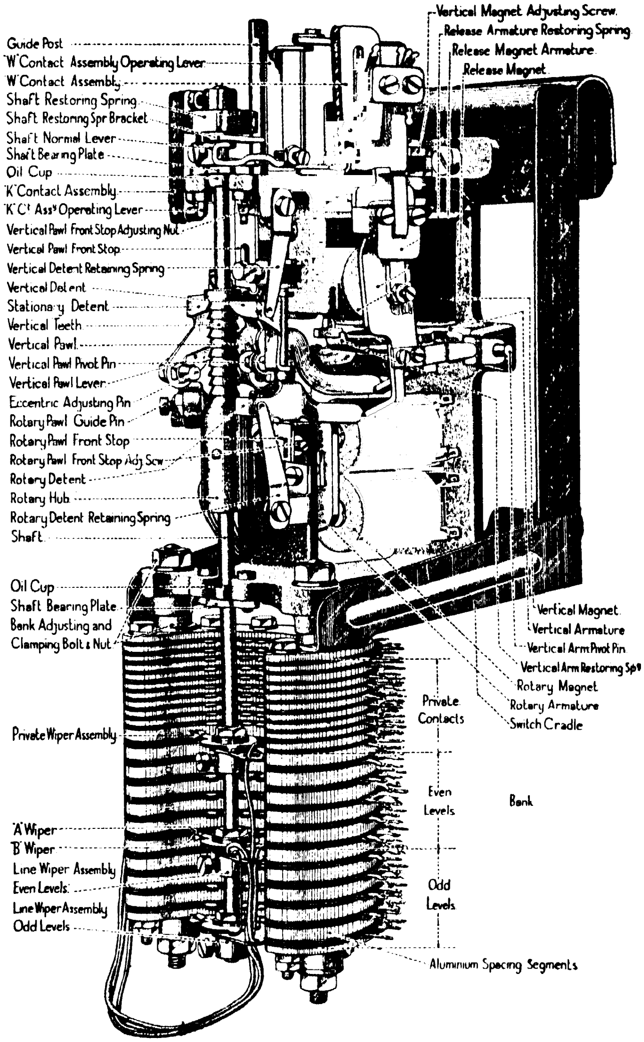


FIG. 545. 2-MOTION SELECTOR—SIEMENS 16 SYSTEM
(Note segregation of odd and even line banks)

1st and 2nd Preselector Circuits. The 1st preselector circuit is shown in Fig. 547. The line relay (*R*) operates to the loop when the subscriber lifts his receiver, and a contact of this relay (***R2***) connects the driving magnet to the motor interrupter contacts. When the wipers make their first step, the *C* wiper disconnects the *C*-wire of the final selector multiple, so busying the line to all hunting final selectors. Relay *T* operates to the

battery on the C-wire when a free outlet is reached. **$T1$** disconnects the drive circuit and provides an alternative holding circuit for relay T in readiness for the release of relay R when **$T2$** and **$T3$** operate. It will be noted that the meter is in series with the C-wire but does not operate at this stage. At the end of the call, the removal of the battery from the C-wire releases relay T, and contact $T1$ completes the drive circuit which is maintained from the homing arc until such time as the mechanism reaches its normal position. The 400 Ω resistor in the C-wire circuit prevents operation of the meter on an incoming call.

The 2nd preselectors are of the non-homing type and hence it is not readily possible to see which mechanisms are engaged. A supervisory lamp is therefore provided per 2nd preselector. A cut-out key is also provided so that any 2nd preselector can be artificially busied and cut out of service when desired. The circuit of the 2nd preselector is shown in Fig. 548. The circuit is seized by the operation of relay R to the earth extended over the C-wire from the 1st preselector. **$R2$** closes the drive circuit. If the wipers are standing on an engaged choice, the mechanism is stepped under machine impulses until the wipers encounter an outlet to a free 1st selector. Relay T now operates to the battery on the C-wire and disconnects the

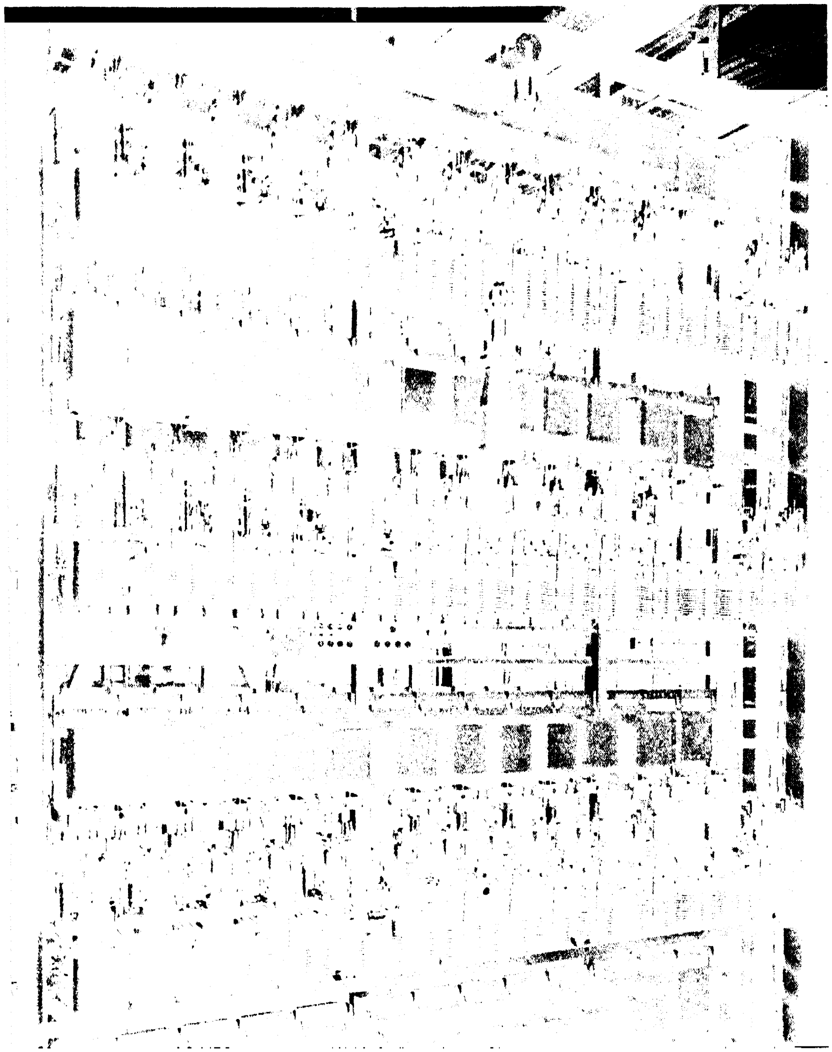


FIG. 546. TYPICAL FINAL SELECTOR RACK

drive circuit at **T1**. Contact **T4** extends the *C*-wire to the 1st selector and removes the short circuit across one of the 500 Ω coils of relay *R*. restoring the circuit to normal. (The wipers remain on the bank contacts of the outlet last used.)

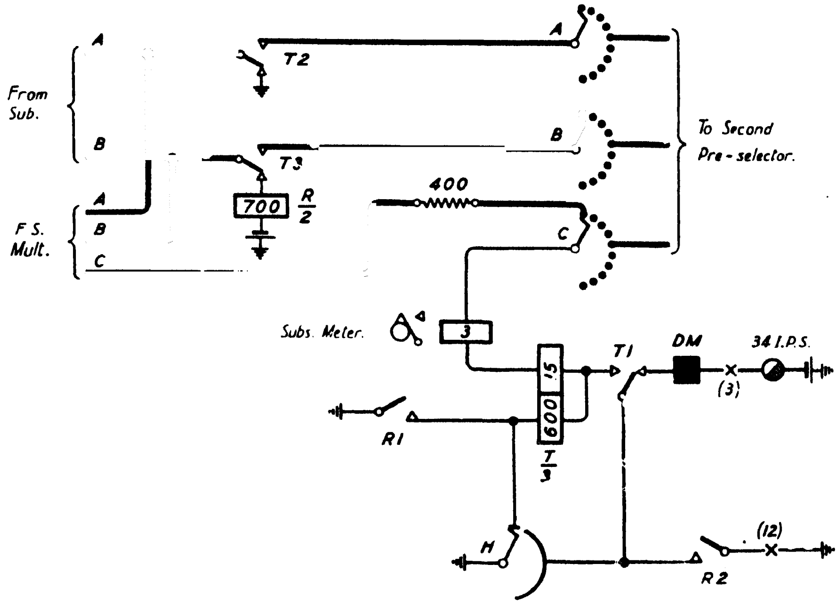


Fig. 547. 1st Preselector Circuit

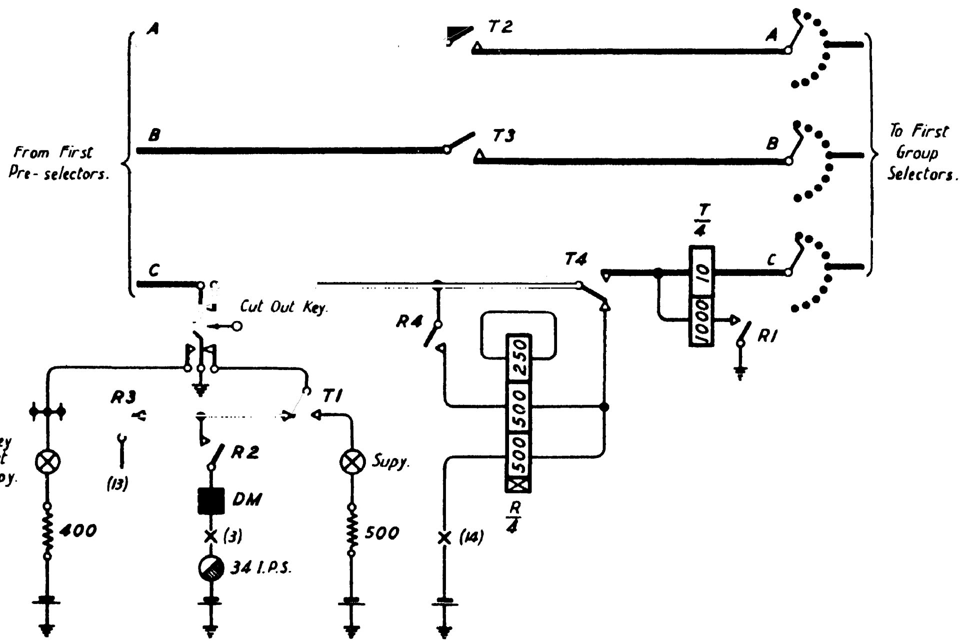


Fig. 548. 2nd Preselector Circuit

The two 500 Ω windings of this relay are differentially connected so that the *R* relay now releases. At the end of the call, relay *T* restores due to the withdrawal of the battery from the *C*-wire, so

Group Selectors. Fig. 549 shows a typical 1st group selector circuit. It will be noted that the transmission bridge is of the Stone type with impedance coils of 350 Ω each winding. The

off-normal (K) contacts are coded $N1$, $N2$, and $N3$ in the diagram to line up with the standard circuit designations. The free condition of the circuit is indicated by battery returned through one coil of relay A, $N1$, $D4$ and the 300 Ω resistor to the C-wire. When the circuit is seized, relay A is pre-operated to the earth applied on the C-wire. When the call is switched through, relay A is maintained from the calling subscriber's loop. The contacts of relay A operate relay V, whilst V in turn operates D. The 1st and 2nd preselectors are now held from the battery returned by contact **V4**.

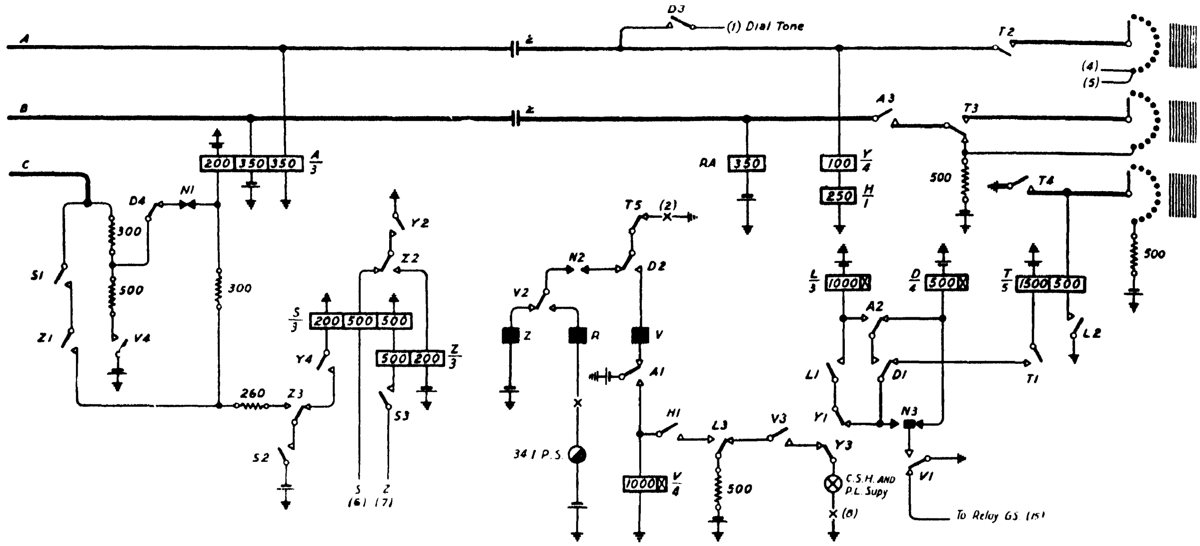


FIG. 549. 1ST GROUP SELECTOR CIRCUIT

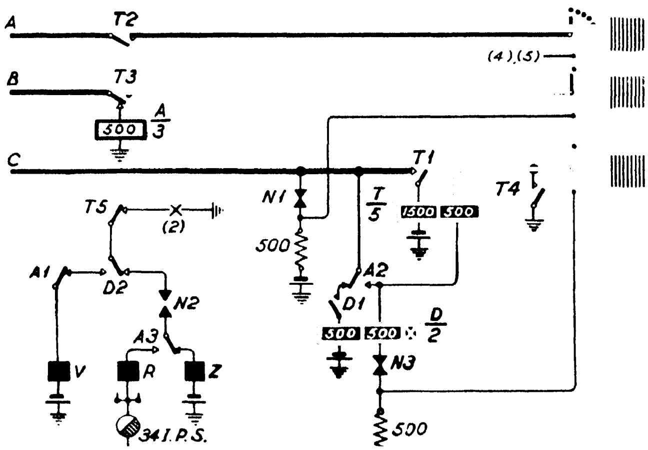


FIG. 550. 2ND GROUP SELECTOR CIRCUIT

Relay A responds to the subscriber's dial and repeats the impulses to the vertical magnet. Relays V and D hold during impulsing, but during the interdigit pause relay D releases and at $D2$ completes the circuit for the rotary drive. When a free outlet is reached (i.e. when a battery is encountered by the C wiper), T operates to switch through the speaking pair and to disconnect the rotary drive circuit. The succeeding impulse trains are received by relay A and are repeated over the B-wire in the form of battery pulses by contact $A3$.

When the called subscriber replies, relays Y and H operate from the called subscriber's loop, and Y in turn releases L. When the first S pulse is received from the ringing machine, S operates and holds. Contacts of the S relay prepare the metering circuits for the receipt, some 2 sec later, of the Z pulse. Relay Z operates to the latter pulse and at **Z1** connects battery via a 260 Ω resistor to the C-wire circuit, so increasing the current flowing in the C-wire, and metering the call against the originating subscriber. At the end of the Z pulse relay S releases to terminate the metering signal at $S1$, but relay Z holds for the duration of the call. The meter, once operated, holds to the normal C-wire current until the connexion is released.

If a call is routed to the automanual switchboard, "Operator Hold" conditions are applied to the calling subscriber. Under these conditions relay H operates to battery on the A-wire, but the current

is insufficient to operate relay Y. The **H1** contact holds relay V and so controls the release of the connexion.

Fig. 550 shows a typical 2nd group selector circuit. The circuit principles are essentially similar to those of the 1st selector, but the diagram is much simpler due to the absence of the transmission bridge, etc.

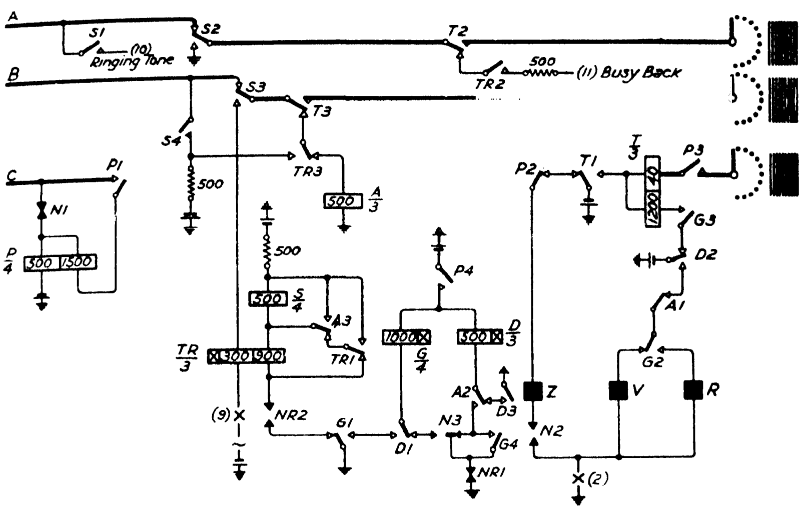


FIG. 551. ORDINARY (NON-P.B.X.) FINAL SELECTOR CIRCUIT

Final Selectors. Fig. 551 gives a schematic diagram of a 100-line final selector without P.B.X. facilities. Relay P operates over the C-wire to the earth extended from the group selector. The impulsing relay (A) operates from the battery applied to the B-wire at the 1st selector, and at **A2** operates relay D. When the first impulse train is received, relay A responds and, by energizing the vertical magnet, steps the wiper shaft to the desired level. On completion of the impulse train, D releases after its slow release period and at $D1$ operates G. **G2** switches over to the rotary stepping circuit, whilst **G4** re-operates D. During the rotary impulse train, the wipers are stepped round to the bank contacts of the called subscriber's line. At the end of impulsing, D again releases after its period of lag, and at $D1$ disconnects the slow-to-release relay G. $D2$ now closes the testing circuit for relay T during the release lag of **G3**, and if the required line is free T operates over both coils in series. The contacts of the T relay switch through the call and release relay A. Relay S now operates to apply ringing current to the called subscriber's line, and ringing tone to the calling party. When the called subscriber replies, TR operates and at **TR1** short-circuits relay S, thereby cutting off ringing current and switching the lines for conversation. If the called subscriber is engaged, relay T cannot operate, and G releases after a delay period to operate relay TR at $G1$. Contacts of TR complete the busy tone and flash circuits.

Apart from the simple final selector illustrated in Fig. 551, there are two types of P.B.X. final selector in the Siemens No. 16 system. The first type of selector provides for P.B.X.s of from 2 to 10 lines and utilizes a "P.B.X. arc" as in the pre-2000 type circuits described in earlier chapters. The second type of final selector provides for P.B.X.s of up to 100 lines. This selector is arranged to search over the lines of one level, and if all these lines are engaged, rotary release occurs. The switch makes one further vertical step, and the search is continued over the next level, and so on.

Incoming Selectors. The Siemens No. 16 system is designed for battery dialling on junction routes, and a special incoming selector is used to give the necessary dialling and supervisory conditions. In some (exceptional) cases incoming junctions are terminated on 1st preselectors where they have

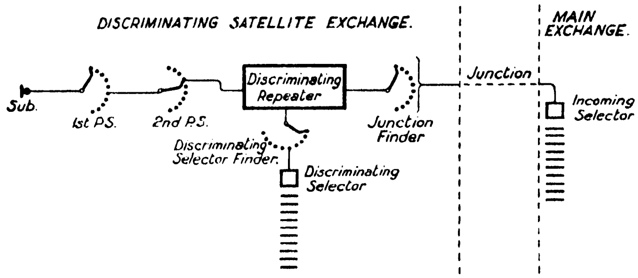


FIG. 552. TRUNKING SCHEME OF DISCRIMINATING SATELLITE EXCHANGE

access via 2nd preselectors to the 1st selectors, but in all other cases the junctions are terminated directly on incoming selectors. The method used in any particular case depends on the volume of traffic and also on whether or not the junctions are worked on a unidirectional or bothway basis. The incoming selector provides manual hold facilities and standard supervisory conditions to the distant exchange operator.

It should be noted that, since the transmission bridge is located in the 1st group or incoming selector, it is not necessary to provide outgoing junction relay sets for the purpose of holding the connexion.

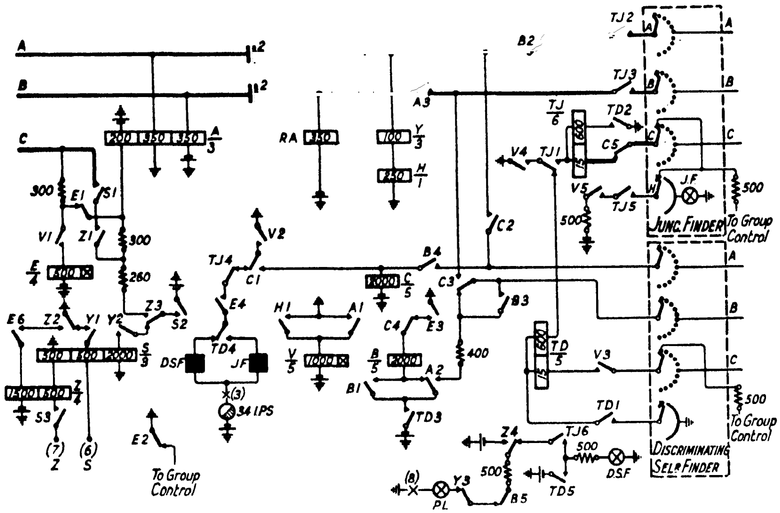


Fig. 553. Discriminating Repeater, Junction Finder and Discriminating Selector Finder

Discriminating Scheme for Satellite Exchanges. It is usual to provide discrimination facilities at the satellite exchanges in a Siemens No. 16 area. The general trunking arrangements at a satellite exchange are illustrated in Fig. 552. When the calling subscriber lifts his receiver, the 1st and 2nd preselectors extend his line to a *discriminating repeater*. This is a relay set, and associated with it are two uniselectors, of which one is used as a *junction hunter* and the other as a *discriminating selector hunter*. Both uniselectors search for and seize first a discriminating selector and then an outgoing junction. The subscriber now receives dialling tone from the incoming selector at the main exchange and proceeds to dial the first digit.

The incoming selector at the main exchange and the discriminating selector at the satellite exchange step to the first digit from the subscriber's dial. The discriminating selector is provided with a vertical marking bank and, if the level reached is the discrimination level, the discriminating selector restores to normal, but is not released. The junction to the main exchange and the incoming selector at that exchange are released, and the second digit is received on the discriminating selector which now functions as a 2nd group selector. If, on the other hand, the call is such that it is to be routed via the main exchange, then the discriminating selector is released and the call proceeds via the junction to the main exchange. In addition to providing discrimination on the first digit, the circuit of the discriminating selector can be arranged to provide discrimination on the second or third digits as required.

Discriminating Repeater. The *A* relay of the discriminating repeater (Fig. 553) is operated on seizure and results in the operation of relays *V* and *E*. The drive circuit of the discriminating selector hunter is now completed and this uniselector continues to search until relay *TD* operates to a free condition on the *C*-wire. The junction hunter now searches for a free junction, and, when one is found, relay *TJ* operates. The calling party receives dial tone over the *A*-wire of the junction and proceeds to dial. On receipt of the first break impulse, relay *B* operates. Contacts *A*2 and *A*3 repeat the impulses to the discriminating selector and to the selector at the main exchange. If the call is for a local number, the discriminating

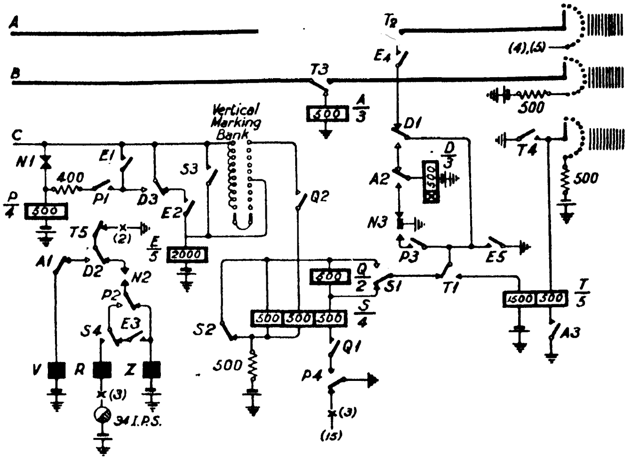


Fig. 554. Discriminating Selector Circuit

selector returns a momentary earth over the *A*-wire on reaching the level dialled. Relay *C* operates and, in turn, releases *TJ* which breaks down the connexion to the main exchange. The operation of the *C* relay also disconnects relay *B* so that all succeeding trains of impulses are transmitted to

the discriminating and subsequent selectors by contact $A3$.

On calls which are to be routed via the main exchange, the discriminating selector disconnects the C-wire on reaching the level dialled. Relay TD releases to disconnect relay B and to release the discriminating selector. The call now proceeds via the main exchange with the $A3$ contact repeating the impulses over the B-wire of the junction.

The two uniselector hunters associated with the discriminating repeater are of the homing type and return to their normal position on release. A group control circuit is provided to prevent either finder from hunting should all the outlets be engaged. Under these conditions, the group control wire is connected to battery, and the seizure of the relay set causes either relay TJ or relay TD to operate, thereby disconnecting the drive circuit to the appropriate uniselector magnet.

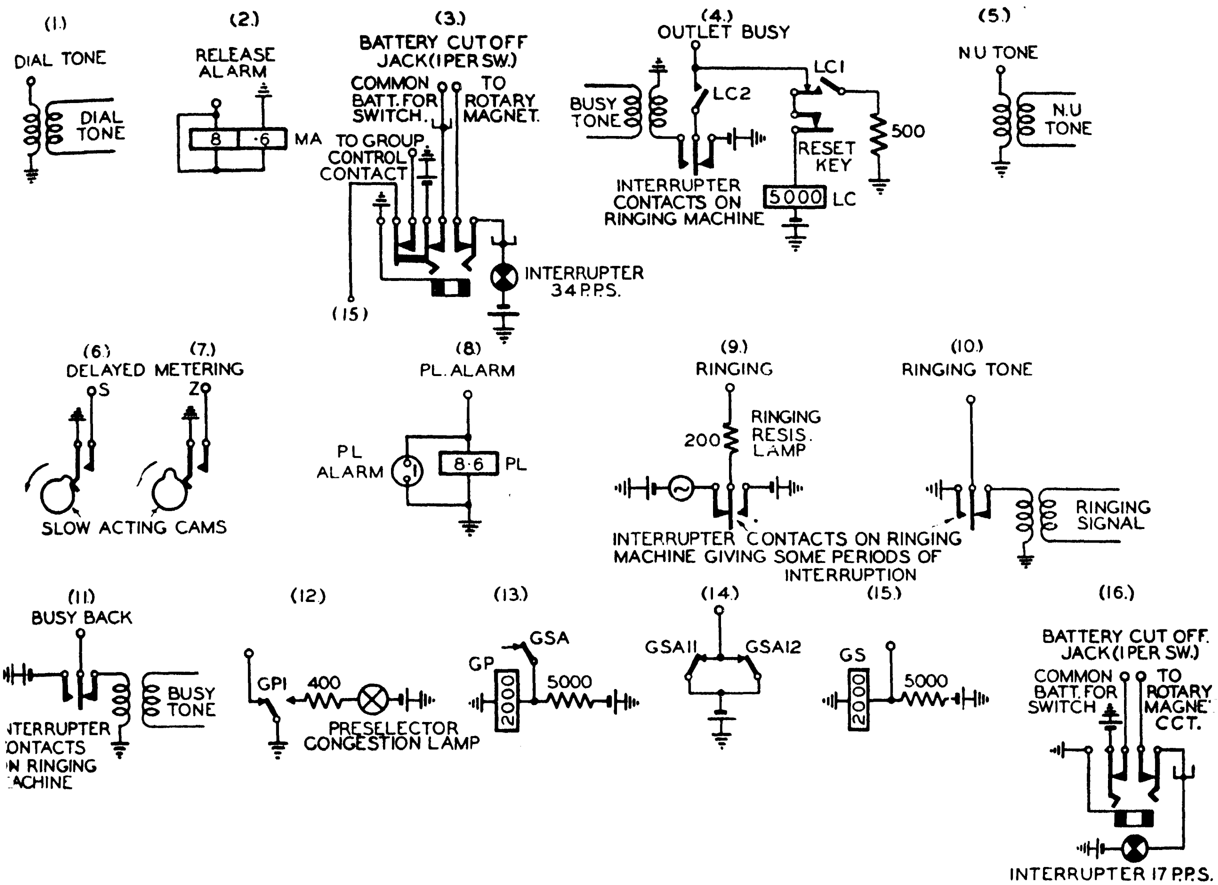


FIG. 555. COMMON APPARATUS, SIEMENS 16 EXCHANGE

Discriminating Selector. The 1st selector associated with the discriminating repeater is shown in Fig. 554. When the selector is seized, relays A and P operate from the conditions on the B- and C-wires respectively. A contact of relay A operates D. Relay A responds to the first train of impulses and operates the vertical magnet in the usual manner. Relay Q operates at the first vertical step.

When the discriminating level (level 5 in Fig. 554) is reached, the vertical marking wiper extends earth to operate relay E. Relay D releases at the end of the impulse train and at $D2$ energizes the release magnet. The selector shaft now restores and, when normal, relay D is operated. D in turn releases E, and the restoration of E allows the operation of relay S. Contacts of S now re-operate relay E and release relay Q. The selector now functions as a 2nd group selector.

When the discriminating selector is stepped to

level 0, relay S is operated from the conditions on the vertical marking bank. **S3** operates E and, when relay D releases at the end of its period of lag, the selector hunts for a free junction to the manual board. The circuit now functions as a 1st group selector, except that the operator hold facility and the transmission bridge are provided by the discriminating repeater.

If the first digit is (in the example shown) other than 5 or 0, relay E does not hold and when relay D releases at the end of the first impulse train, the C-wire is disconnected. This in turn releases relays TD (discriminating repeater) and A.

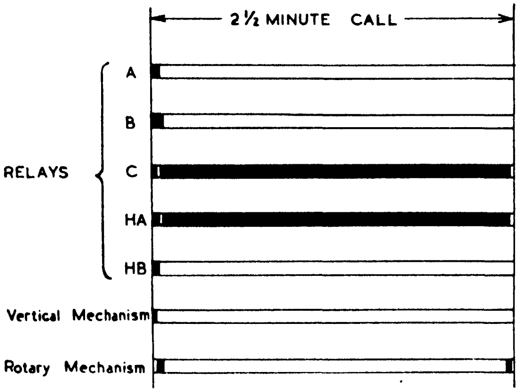


FIG. 556. SHOWING TIMES FOR WHICH VARIOUS PARTS OF A GROUP SELECTOR ARE IN USE DURING AN AVERAGE CALL

Discrimination on the second or third digit follows the principles already described above, but additional relays are required to defer the transmission of the discriminating signals on the A- or C-wire.

Common Services. Fig. 555 shows the various supervisory relays and other services which are common to a number of circuits. The numbers in parentheses indicate the points on the various selector diagrams to which the common services are applied.

STROWGER COMMON CONTROL SYSTEM

Common Control. Each selector in the standard Post Office system has its own group of controlling relays. Most of these relays are required only whilst the call is being established and are not required during the much longer conversational time of the call. It would appear, therefore, that these relays could be more profitably employed if they were associated with the selector circuit only during the process of selection so that they could be used for the establishment of other calls during the conversational time. A 200-outlet group selector of the type illustrated in Fig. 355 has a total of five relays, of which three are no longer required once the wipers have been positioned on a free outlet in the selected level. The periods of use of the various relays, etc., are clearly illustrated in Fig. 556. The A and B relays, and one of the switching relays (HA or HB) are required only for a period of some 2 sec, and remain idle for upwards of 2 min on a call of average duration. The control circuit of a final selector is even more inefficient in its use of relays. In this case, a number of relays are required to change over from vertical to rotary stepping, to trip the ringing current, to control metering, and in some cases to provide the automatic search feature over P.B.X. groups. In the 11-and-over type P.B.X. final selector illustrated in Fig. 359, for example, there is a total of 15 relays, although only 3 of these are operated whilst the call is in progress. There is no fundamental reason why the relays which are required only during the setting up of a call should not be placed in a common relay group which is capable of being switched to one of a number of selectors as required.

Apart from the question of initial cost, the *common control* principle has also some advantages in that the relays with the most critical performance limits (e.g. impulsing circuit relays, testing relays, etc.) are the ones relegated to the common control circuit. The consequent reduction in the number of such relays results in some economies in maintenance.

The reduction in the number of relays obtainable by the use of common control circuits must be weighed against the cost of providing equipment for coupling the common control circuit to a particular selector as required. Moreover, the use of a common controlling circuit for a number of selectors necessarily limits the number of calls which can be established simultaneously to the number of control circuits which are available. If, for example, one common control circuit serves, say, 10 selectors, then it is not possible to set up more than one call at a time on this group of switches. This in turn necessitates the artificial busying of all free selectors in the group whenever the control circuit is in use. The consequent reduction in the traffic carrying capacity of the switches must be added to the cost of providing the coupling equipment between the control circuit and the selectors, and this total cost must be weighed against the saving of relays resulting from the use of a common control circuit. In some instances the cost of a common control scheme may be actually greater than the cost of providing separate controlling circuits in each selector. Ease

of maintenance, and the effect of control circuit faults on the overall grade of service, must also be considered. Generally speaking, it is more difficult to trace and locate a fault on any system employing common control principles, whilst a fault in the common control circuit may produce a serious degradation in the grade of service.

Common Control of Incoming Selectors. There are some special problems in the application of the common control principle to selectors which are directly connected to incoming junctions. The number of such selectors is, of course, equal to the number of junctions, and in any particular case the total number of junctions is only just sufficient to carry the busy hour traffic. If, therefore, the common control principle is applied to the incoming selectors, not only are all free selectors in the common control group engaged whilst the control is dealing with one call, but all the junctions associated with these free selectors are also artificially busied. Thus, the adoption of common control necessitates some increase in the number of junction circuits in order to maintain the grade of service. Junctions are, as a rule, very expensive, and this factor alone makes it extremely difficult to justify any system of common control on incoming selectors.

There are also some major technical difficulties. In the absence of 3-wire junctions, it is not readily possible to transmit a signal back on the free junctions (when the common control is in use) in order to engage the outgoing end of the junctions. The group of selectors served by one common control circuit may serve junctions from several different exchanges, and in this case there is no alternative to the return of an engaging condition from the incoming end of the circuits. Although such a signal can be devised, difficulties occur in arranging for the outgoing terminations to be busied sufficiently quickly to prevent calls slipping through irregularly to an incoming selector associated with an engaged control circuit. If all the junctions of one common controlled group are from the same distant exchange, it may be possible to engage the circuits at the outgoing end on receipt of a signal returned over the junction which is engaging the common control set. Here again, there are appreciable technical difficulties in designing a scheme which is effective under all conditions of service. (It should be noted that a common control circuit may be engaged for a very short time or for a comparatively long time on the setting up of one particular call.)

The above difficulties could be overcome by terminating the incoming junctions on selector finders or on the banks of junction hunters, but the cost of such equipment would generally outweigh the savings obtainable by the use of common control principles. Selector hunters or junction finders do, moreover, introduce a delay which is usually intolerable, especially on junctions accessible from selector levels at the outgoing exchange. (There is insufficient time between successive digits to allow for the automatic search of both the selector at the outgoing exchange and the uniselector at the incoming termination.)

We have seen (Chapter XIII) that the standard director circuit includes a "hold-up" feature which was initially included for suspending impulsing on calls to manual exchanges until a free coder is available. This feature could be used to suspend dialling over a junction until the common control set which serves the incoming selector is available.

Common Control of Final Selectors. At a first glance it would appear that the principle of common control could be applied to final selectors with particular advantage. Such selectors contain a large number of relays for the direction of the impulse trains first to the vertical and then to the rotary magnet for the control of metering, to provide automatic ring-trip facilities, and so on. Basically the selector requires only the two transmission bridge relays and a guard relay throughout the conversational period.

A further examination, however, will show that difficulties arise due to the wide variations in the holding time of the control circuit which would occur if all the controlling relays were located in the common control circuit. In the first place, the holding time of the control is necessarily somewhat longer than on group selectors due to the fact that a final selector must accept *two* digits to direct the wipers first vertically and then in a rotary direction to the required number on the selected level. If the line is free, the ring-trip relay must be associated with the selector until such time as the called subscriber replies. Similar conditions exist with regard to the relays required for metering. Unlike group selectors, it is not possible to return engaged conditions by the use of 11th step contacts, and, if a call is ineffective due to the called line being engaged, the busy relay of the final selector is required until such time as the call is abandoned. Although the *average* holding time of a comprehensive common control circuit would not be excessive, there is a danger of serious degradation of the service should the common control be held for an abnormal period on one particular call. If, for example, the ring-trip and metering relays were associated with the common control circuit, and the circuit was held by a subscriber for, say, ten minutes on a "no

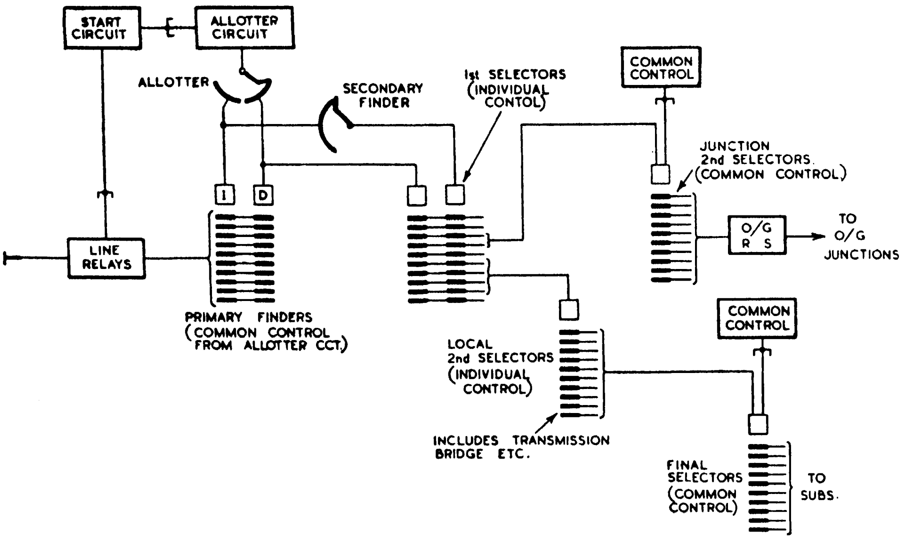


FIG. 557. GENERAL TRUNKING ARRANGEMENTS OF WIGAN COMMON CONTROL SCHEME

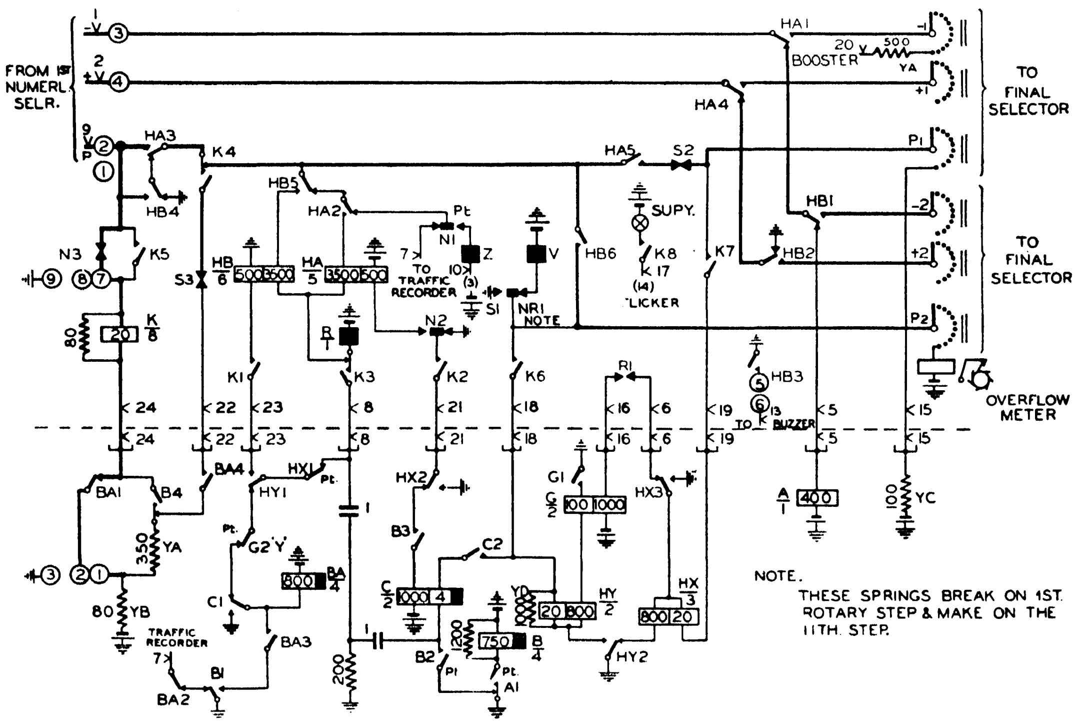


FIG. 558. TYPICAL 200-LINE GROUP SELECTOR (PRE-2000) WITH COMMON CONTROL

reply" call, the whole of the group of final selectors served by that control would be out of service during this period.

In practice it is very difficult to justify common control of any selector which contains the ringing, metering, etc., elements which must be held until the call is switched for conversation.

Wigan Common Control Scheme. About the year 1931 the Automatic Electric Company, Limited, designed a system utilizing common control principles in conjunction with their standard Strowger switching scheme. An experimental exchange was installed at Wigan in 1933 and is still in service. The general trunking arrangements are shown in Fig. 557. The exchange utilizes 200-point linefinders with partial secondary working. The 1st selectors have individual controlling relays (i.e. there is no common control) since it was not considered to be of any advantage to apply common control at this stage owing to the wide variations which occur in the holding time of 1st selectors. The transmission bridge, ringing relays, etc., are located in the 2nd selectors which serve local groups, and these selectors are also individually controlled. The 2nd selectors serving levels 7 and 8 give access to outgoing junctions. These selectors are provided with common control relay sets so that one relay set can serve up to a maximum of 13 group selectors. All the final selectors are of the common control type, and the arrangements are such that one control set can serve up to a maximum of 9 final selectors. The difference between the maximum ratios of these two ranks of selectors is due to the lower holding time (2·0 sec) of the common control circuits for the 2nd selectors, as compared with a figure of 3·5 to 4 sec for the common control serving the final selectors. This difference is due primarily to the fact that the final selector accepts two digits as compared with the one digit received by the group selector.

The 2nd group selectors served by a common control each contain 2 relays which serve as switching relays for the odd- and even-numbered outlets, together with a 3rd relay for associating the selector with the common control circuit. The associated common control circuit has a total of 10 relays. The final selectors have a switching relay, a wiper switching relay, and a relay for associating the selector with the common control. The control circuit in this case has a total of 9 relays.

200-outlet Group Selector with Common Control. Fig. 558 shows the application of common control principles to a group selector. The circuit arrangements follow typical pre-2000 type practice with relays HA and HB serving as switching relays. The additional relay (K) is added to the selector circuit for the purpose of switching to the common control relay set.

If the control relay set is not in use, battery is returned on the P-wire of all disengaged selectors in the group to indicate the free condition. The switching relay of the preceding selector operates to this battery, and in so doing applies a low resistance earth to the P-wire. This earth effectively shunts out the testing battery so that all other selectors associated with the control set are temporarily engaged to traffic. When the group selector switches to a disengaged trunk, relay HA or relay HB operates to switch the call and to disconnect the circuit of relay A in the control set. $A1$ in turn releases B, and $B4$ disconnects the holding circuit for relay K. $K4$ in restoring now completes the holding circuit of the switching relay to the earth on the P-wire, and the release of $K5$ removes the engaging condition from the P-wires of the remaining free selectors in the group. The remaining contacts of relay K disconnect the various leads between the selector and the control set, and the latter is now available for use on other calls.

EXERCISES XVIII

1. Explain, with the aid of a diagram, how traffic from the subscribers' lines in a Siemens No. 16 System is concentrated on the available 1st selectors. Discuss the merits and limitations of this scheme when compared with a system utilizing 24-point uniselectors with graded outlets.

2. Show how, in a Siemens No. 16 System, a 1st preselector is made to search for and to seize a free 2nd preselector. What provision is made in the 1st preselector circuit to guard against re-seizure during the restoration of the preselector mechanism at the end of a call?

3. The preselectors of a No. 16 System are stepped by means of machine generated impulses, whereas the uniselectors of the standard automatic system are stepped by means of interrupter contacts associated with the driving mechanism. Discuss the relative merits of these two methods. Why is it advisable to prevent continuous hunting of the preselectors in a Siemens No. 16 System under full congestion conditions?

4. Describe, with the aid of simple sketches, how the impulse trains from the subscriber's dial are transmitted to the 2nd, 3rd, and final selectors

in a Siemens No. 16 exchange. How does the method of impulsing within the exchange affect the position of the transmission bridge in the No. 16 System?

5. Describe (with the aid of simple diagrams) how an effective call is metered against the calling subscriber in the No. 16 System. Compare this method of metering with the positive battery metering scheme used in the current standard system.

6. Examine the method of testing used between successive selector stages in the Siemens No. 16 System. Show to what extent the system guards against dual connexions due to two circuits testing the same outlet concurrently. Illustrate your answer by calculating the current in the testing relay under single testing and dual testing conditions.

7. Describe what is meant by "common control" when applied to selector circuits. What are the objects of adopting common control methods and what are the basic economic factors which determine whether common control is more economical than individual control under any particular conditions?

8. Discuss the difficulties of applying common control principles to the 1st and incoming selectors of an automatic exchange. Does the use of common control affect the number of incoming junctions to an exchange?

9. If you were considering the design of a common control circuit for use with final selectors, would you locate the busy relay and the ring-trip relay in the selector circuit or in the common control circuit? Why?

10. In any system of common control there are two main methods of associating the selector circuit with the control circuit, i.e. by the use of a switching relay or by the use of a uniselector mechanism. Discuss the merits and limitations of these two alternative methods.

CHAPTER XIX

MARKER CONTROL UNISELECTOR SYSTEMS

All the automatic switching systems so far considered in this volume have been built around the use of the Strowger 2-motion selector as the main switching mechanism. With such mechanisms it is possible to direct the wipers to any desired level simply by means of a train of impulses from the subscriber's dial (or from a storage device such as a director). The wipers can then be moved to any desired contact on the selected level either by means of a further train of impulses or by an automatic search action as in the case of group selectors. The chief characteristic of the 2-motion selector is that any one contact out of a total bank capacity of 100 or 200 can be reached by not more than 20 steps of the selector mechanism (i.e. 10 vertical and 10 rotary steps). This facility provides a simple and straightforward trunking scheme, and it is readily possible to trace any connexion through the exchange. The 10 (or 20) outlets per level provide a reasonable trunking efficiency in most circumstances.

It is readily possible to design an automatic switching system without the use of 2-motion selectors, and there are in fact a large number of successful and widely used automatic systems in which the process of selection is obtained by the use of mechanisms where the wipers move in one plane only, i.e. mechanisms of the uniselector type. In the early paragraphs of this chapter an examination is made of some of the problems concerned in the design of a uniselector switching system, whilst the latter part of the chapter describes the main features of representative systems based on the use of uniselector mechanisms with individual drive.

Unidirectional versus 2-motion Mechanisms. Some authorities contend that one of the chief disabilities of the 2-motion selector is the inherent inflexibility of the mechanism. The outlets from the selector bank are subdivided into 10 distinct groups each of equal size (i.e. one group per level of the selector). This subdivision of the available outlets is no material disadvantage if the volume of traffic to be routed over each level is approximately the same. In some cases, however, one or two levels of a particular group of selectors may carry a heavy volume of traffic, and a material increase in the trunking efficiency is obtainable if the availability of that level could be increased beyond the normal 10 (or 20) outlets. Other levels of that same selector may carry very little traffic, and full availability conditions can perhaps be obtained by considerably less than the normal 10 (or 20) outlets on the levels. In the extreme case a selector may have one or two very heavily loaded levels, with the remaining levels completely spare. These spare levels (or the unused contacts of lightly loaded levels) cannot be used to increase the trunking efficiency of the levels which carry a high volume of traffic.

The problem is illustrated in Fig. 559 which shows typical routing arrangements from the levels of a 1st selector. As we have seen in earlier chapters, level 1 is excluded from the numbering scheme (on account of the possibility of false initial impulses), and hence only a comparatively small number (e.g. 5) of circuits to N.U. tone equipment is required from this level. Levels 2, 3, and 4 are utilized for giving access to local 2nd selectors, and these levels carry a high volume of traffic. Levels 6 and 7 are spare, whilst levels 8 and 9 carry a comparatively small volume of traffic. It is clearly impossible (without materially complicating the circuit arrangements) to utilize the spare contacts on levels 1, 6, 7, 9, etc., in order to increase the availability of the heavily worked levels 2 and 3.

Fig. 560 shows a possible alternative trunking scheme utilizing a mechanism of the unidirectional type. It is assumed that this uniselector mechanism has the same total number of outlets (i.e. 200) as the 2-motion selector shown in Fig. 559. There is now no artificial subdivision of the outlets on the selector bank, and the 200 contacts of the uniselector can be grouped as required to meet the varying traffic density of the outgoing routes. The first 5 contacts can be routed to N.U. tone to serve the "level 1" group, the next 50 contacts can be allocated to "level 2," whilst "level 3" is served by the following 60 rotary positions of the uniselector bank and so on. In this way it is possible to provide full availability on all traffic groups and at the same time to leave 15 spare contacts which can be made available to meet growth on any one of the individual groups. This arrangement clearly increases the trunking efficiency of the system. On traffic to "level 3" subscribers, for example, the full availability group of 60 circuits obtained by the arrangement shown in Fig. 560 will carry some 42 T.U. of pure chance

traffic. The same total number of trunks, when connected to a level of a 2-motion selector (with an availability of, say, 20) would carry only about 25 T.U. for the same standard grade of service. Conversely, if the maximum busy hour traffic is, say, 25 T.U., then the standard grade of service can be given by a total of 52 trunks when there is

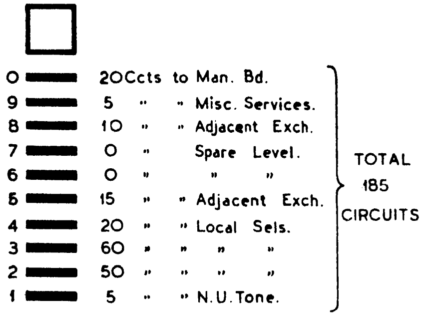


FIG. 559. UTILIZATION OF THE LEVELS OF A 1ST SELECTOR OF THE 2-MOTION TYPE (200-OUTLET)

full availability, as compared with the 60 trunks required with a 2-motion selector having an availability of 20 per level.

The theoretical increase in the trunking efficiency which is obtainable by the use of unidirectional mechanisms must be examined in conjunction with

(*a*) the relative cost and complexity of the mechanisms and their control circuits,

(*b*) the ease with which changes in group size can be made during the life of the exchange, and

(*c*) the ease of tracing calls.

Unidirectional type selecting mechanisms show up most clearly to advantage in switching stages where one or two heavy traffic groups are mixed with a number of lightly loaded groups.

There is a further argument for the use of unidirectional rather than 2-motion selectors in a switching system. Selectors of the latter type are necessarily somewhat complex owing to the more or less complicated movements of the wipers. Generally speaking, the mechanism necessary to position the wipers on a unidirectional switch is less costly and less elaborate than the mechanism required for a 2-motion selector. In each case the positioning mechanism is required only for a few seconds during the establishment and release of a call, and is completely idle during the much longer conversational period for which it is engaged. Any system which requires complex mechanisms which are idle for a large part of the time (even during the busy hour) is clearly less efficient than a scheme in which the equipment which lies idle during the conversational period is less elaborate and less costly. These economies must, of course, be offset by any possible complications in the control circuit of the unidirectional mechanism.

An additional factor which must also be considered is the space required by the selecting mechanisms to give the same overall facilities. In general, the mechanisms of the unidirectional type require less rack space than selectors of the 2-motion type—due primarily to the simplification of the positioning mechanism. A comparatively small reduction in the size of the selector can produce material economies in the cost of the apparatus racks, of the building and of the site required to house a large exchange.

Control of Unidirectional Mechanism by Dialled Impulses. Possibly the greatest merit of the 2-motion selector is the ease with which the wipers can be directed to the required group of outgoing trunks. The mechanical design is such that the wipers are automatically positioned adjacent to the selected group of trunks immediately after the termination of the last impulse of the selecting digit. These facilities are not readily available on mechanisms of the unidirectional type. Conditions somewhat similar to those on a 2-motion selector can be obtained on a unidirectional selector by

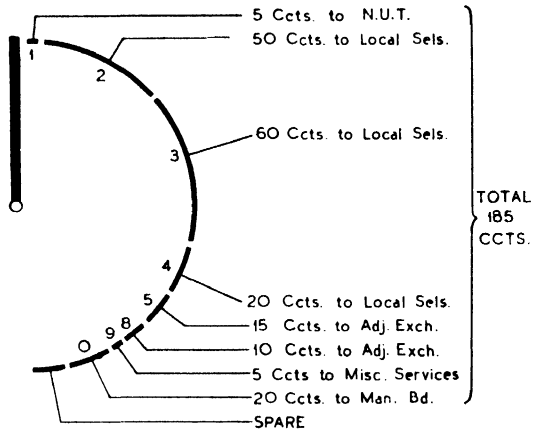


FIG. 560. SHOWING THE MORE FLEXIBLE ARRANGEMENTS OBTAINABLE BY THE USE OF A UNIDIRECTIONAL MECHANISM

providing a number of wipers connected in parallel, and designing the mechanism so that the wiper opposite the required level only is "tripped" by the selecting impulse train. Such mechanisms are used in the Rotary System (q.v.), but they do not give the trunking flexibility of a true uniselector mechanism and are more nearly comparable to selectors of the 2-motion type. It is not readily possible to design a unidirectional mechanism of

simple construction in which the wipers can be stepped to the commencement of the required group of trunks direct by the impulse train—especially if flexibility in the size of groups is required.

In general there are two main methods of positioning the wipers of a unidirectional selector to the commencement of a group of trunks or on to a particular outlet. The first method consists fundamentally of providing impulsing contacts on the mechanism of the selector so that a series of signals is passed back to the control circuit as the wiper moves from contact to contact. The control circuit is designed to count these pulses and so to determine the correct point at which to arrest the wiper movement or to initiate search over a group. Such systems are known as *revertive impulse systems*, and are described in the next chapter.

An alternative method is to arrange for the control circuit to receive the dialled impulses, and to use these impulses to set up marking conditions on the banks of the uniselector so that search is made only over the correct group of outgoing trunks. (If the uniselector is serving as a final selector, the control circuit marks the *exact* contact at which the movement of the wipers is to be arrested.) Schemes which employ this principle may be designated *marker control systems*.

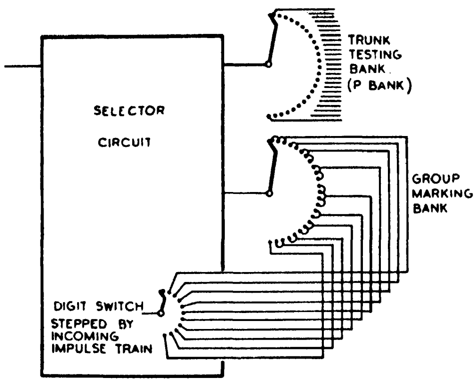


FIG. 561. MARKER CONTROL PRINCIPLE FOR SELECTING REQUIRED GROUP OF TRUNKS ON UNISELECTOR BANK

The principle of marker control is illustrated in Fig. 561. An additional arc of the uniselector bank is required to accommodate the marking conditions from the control. The contacts of this bank are commoned as required to give the necessary grouping of contacts, and the marking wires to these groups are terminated on the banks of a separate impulse counting switch (or *digit* switch). The circuit arrangements are such that the counting switch is stepped by the impulses received from the subscriber's dial, and, at the end of the impulse train, a suitable marking condition is applied via the counting switch to the appropriate portion of the main selector bank. At the appropriate time the selector is caused to hunt over the bank but to test only those trunks which are

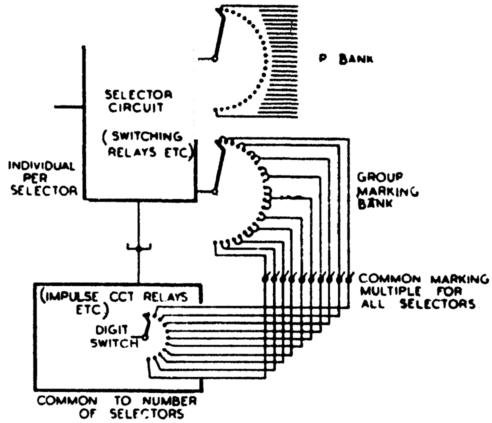


FIG. 562. MARKER SYSTEM WITH COMMON CONTROL CIRCUITS

marked by the digit switch. With this scheme flexibility in the trunk grouping and simplification of the main selector mechanism are obtained only by the provision of an additional digit counting switch. The cost of this switch must therefore be offset against the increase in trunking efficiency, and the lower cost of the main selector mechanism.

There are, however, certain advantages which make this method of control economically practicable and in some cases less expensive than 2-motion selectors. In the first place the marker control system lends itself particularly to common control principles (Fig. 562). The marking multiple is common to all selectors of a particular stage, and the digit counting switch, together with its associated control relays, can readily be placed in a common circuit. A number of schemes have been devised in which, say, a group selector consists of a simple uniselector mechanism with several switching relays permanently associated with it, the remainder of the controlling relays and the digit counting switch being located in a control circuit which is in use only during the setting up of a call and is available, as required, to a number of selectors.

The marker control principle also makes it possible to adjust the size of the various groups of trunks by means of simple strappings on terminal strips associated with the marking arcs of the

selectors. The scheme is completely flexible, and it is possible to break up the groups of trunks in any desired manner. This facility is particularly useful when additional trunks are required in an existing group. The additional outlets can be located at any convenient point on the bank without the necessity of rearranging the positions of the remaining groups of trunks.

Possibly one of the greatest merits of a marker control uniselector system is the segregation of the impulse counting device from the selector proper.

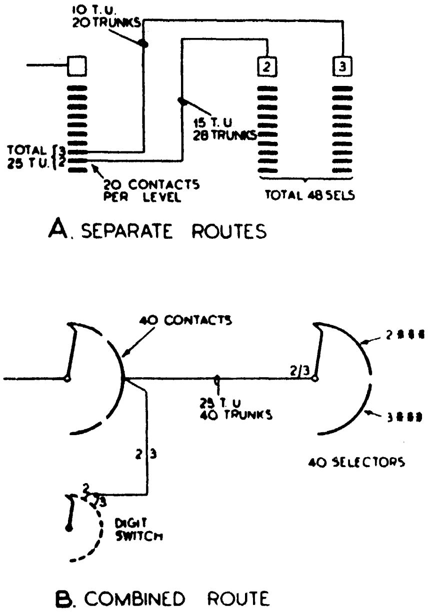


Fig. 563. Showing How a Marker Controlled Uniselector System Lends Itself to Combined Group Working

We have seen (Chapter V) how the relays of the impulsing circuit and the characteristics of the selector magnet determine the impulsing performance of an automatic switching system. During recent years various improvements in the impulsing circuit and in the characteristics of the relays have materially increased the available margin of distortion. Further improvements can be obtained only by reducing the time required for the operation and release of the selector magnets themselves. The magnet characteristics are in turn largely determined by the amount of mechanical work to be done in moving the wiper carriage. Where, as in the 2-motion selector, the magnets are required to move the main selecting wipers of the mechanism, any improvement can be obtained only by reducing the mass of the moving system and the frictional load of the wipers, etc. There is a point beyond which it is not possible to reduce the mass of the moving parts of a selector mechanism whilst still retaining a sufficient degree of robustness to ensure long life and low maintenance costs. In a marker control system the impulse counting (or digit) switch can be specially designed to give a good impulsing performance, whilst the main switch mechanism can be designed to give the required mechanical characteristics without regard to impulsing requirements. The digit switch can, in fact, be replaced if desired by a relay or electronic type of counting circuit which would give a greatly increased margin for impulse distortion.

Combined Trunk Groups. A uniselector system with marker control makes it possible, in some circumstances, to increase the trunking efficiency (and in some cases to reduce the number of stages of selection) by combining two or more groups of trunks between successive stages of selection. For purposes of illustration let it be assumed (as in Fig. 563) that the busy hour traffic densities on levels 2 and 3 of the 1st selectors in a certain exchange are 15 T.U. and 10 T.U. respectively. If the switching scheme utilizes 2-motion selectors of the 200-outlet type, 28 trunks are required from level 2 and 20 trunks are required from level 3 in order to give the standard grade of service with pure chance traffic. If means can be found of bulking the traffic on these two routes and providing one common group, a full availability group of 40 trunks will suffice to carry the total traffic of 25 T.U. Conversely, if the availability is restricted to 20, the total traffic of 25 T.U. can be carried by a grading consisting of 44 trunks. Thus, by utilizing the full 40 bank contacts, it is possible to obtain a saving of some 8 trunks to the next switching stage (and, of course, a saving of the same number of selectors in the next stage).

On the other hand, if the availability of a combined group is restricted to that of each of the individual groups (i.e. 20), there is a very slight saving in the number of trunks (i.e. 4), but the scheme frees 20 outlets of the selector bank for other use. It may be possible to utilize the bank capacity made available in this way to reduce the number of switching stages required in a particular exchange. The economic advantages of combining groups of trunks are most pronounced when the traffic on the component parts of the group is small, as in the above simple illustration, but there is nevertheless often a worthwhile saving even with large volumes of traffic.

It is not readily possible to adopt combined group working with selectors of the 2-motion type. Such facilities can be devi ed, but they involve

comparatively complex circuit arrangements in order to provide for search over two consecutive levels (or, alternatively, for impulse absorption if the combined group occupies one level only). These problems do not apply to an automatic system which utilizes selectors of the unidirectional type. We have seen that the number of contacts allocated to each group of outgoing trunks can be adjusted with a high degree of flexibility. It is readily possible to arrange the connexions between the digit receiving switch and the marking multiple so that search is made over the same common group of trunks when two or more different digits are dialled. Such an arrangement is shown in the lower part of Fig. 563. Bank contacts 2 and 3 of the digit switch are commoned together so that, when either of these digits is dialled, the marking condition is applied to a group of 20 contacts on the main selector bank.

The adoption of combined group working necessitates some form of signal to the next switching stage to differentiate between the various types of traffic over the common group of trunks. In Fig. 563, for example, it is necessary to pass a signal forward to the next selector to indicate whether the number required is in the "2" or in the "3" group of numbers. If only two groups are combined, a simple discriminating signal will suffice to operate a discriminating relay in the next switching stage in order to switch the wipers to the appropriate bank or group of outlets. The discriminating signal can be obtained from the positioning of the digit receiving switch (e.g. 2 or 3), or it may consist of a separate signal sent out by a register circuit subsequent to the selecting digit (2 or 3). If facilities are required for combining three or more groups of trunks, the differentiating conditions become somewhat more complex. One method, which can be used on systems utilizing registers, is to arrange for the repetition of the selecting digit to set up the correct discriminating conditions in a subsequent selector. Thus, if levels 2, 3, and 4 of the 1st selector are served by a common group of trunks to 2nd selectors, it would be possible to indicate to the 2nd selector the correct routing by repeating the initial digit (i.e. 2, 3, or 4) after the 1st selector had seized the 2nd selector. The repeated digit could then be used to operate a switch in the 2nd selector circuit to set up the appropriate discriminating or wiper switching conditions.

The savings produced by an increased trunking efficiency obtainable from the use of combined groups must, in all cases, be weighed against the cost of providing the necessary discriminating conditions to the next stage of selection.

Selection During Interdigit Pause. A short time interval (the interdigit pause) is required between successive digits in any automatic system to allow the mechanisms to search for and seize a selector of the next rank in readiness for the succeeding digit. We have seen (Volume 1) that the standard dial of the British automatic system is designed to give a pause of 200 msec before the transmission of each impulse train. To this must be added the time taken by the caller to pull the dial round to the finger stop and, under the most adverse conditions, the interdigit pause is in the order of 400–500 msec. Some 150 msec of this interdigit pause is required to provide the end-of-impulse-train switching signal (the release of the C relay in the standard system). There is therefore a period of from 250–350 msec available for a group selector to search for a free outlet in the selected group, to switch to this outlet, and to prepare the circuit seized for the reception of the next impulse train. For design purposes, the time available to search for a free trunk may be assumed to be, say, 300 msec.

When the switching system employs group selectors of the 2-motion type, the wipers are positioned adjacent to the first contact of the selected level at the termination of the last impulse of the train. These wipers may be required to make a maximum of 10 steps during the 300 msec which is available for search. It is clear, therefore, that for complete safety a rotary hunting speed of some 33 steps per second is required. This was not obtainable on some of the pre-2000 type circuits which employed an interacting-relay type of rotary drive, but the more modern circuits, employing 2000 type selectors (with the toggle interrupter) provide a hunting speed which more nearly approaches the theoretical minimum.

The employment of a unidirectional type selecting mechanism very materially increases the difficulties of ensuring completion of search during the interdigit pause. The modern 2-motion selector provides a total of 200 outlets. A simple uniselector of the same capacity may, under the most adverse conditions, have to move the wipers over 200 contacts during the interdigit pause. If the available period for search is assumed to be 300 msec as before, then it is clear that the uniselector should have a hunting speed of 666 contacts per second. (This assumes that the selector movement does not commence until the end of the impulse train, i.e. that the whole of the movement takes place during the interdigit pause.) Such a phenomenally high hunting speed is virtually impossible on a mechanism which must be large enough to accommodate 200 outlets. Even

if it were possible to design such a mechanism, there remains the problem of arresting the movement of the wipers when the required contact has been reached. At a speed of 666 contacts per second, the wipers rest on each contact for somewhat less than 1 msec. During this time the testing relay must respond to the free condition, and the

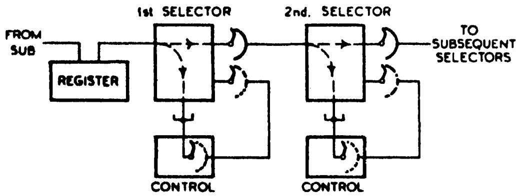


Fig. 564. Outline of Marker Control System with Registers

selector drive must be cut. Various methods have been employed by designers to overcome this fundamental difficulty with uniselector type automatic systems. The methods employed for keeping the time of search within the required minimum period do, in fact, largely account for the differences in the various systems of this type.

One obvious solution is to record the incoming impulse trains from the subscriber's dial in a suitably designed register circuit, and then to pass signals forward from the register to provide the necessary group selection at the various switching stages (Fig. 564). The circuit arrangements could then be such either to provide a sufficient period between successive selecting signals from the register to enable the mechanisms to complete their search or, alternatively, arrangements can be made so that the signals from the register are suspended until each successive selector seizes a trunk to the next switching stage. Both methods have been used successfully, but they involve the provision of comparatively complex register circuits on all calls. There is, moreover, a practical limit to the hunting time which is determined by the necessity for establishing a connexion within a reasonable period.

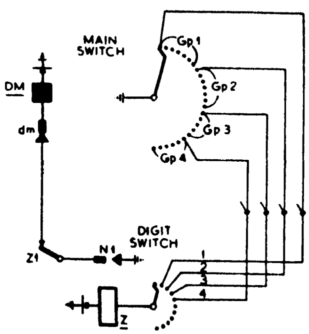


Fig. 565. Impulse Chasing Principle to Increase Time Available for Search

If registers are not to be used, it is necessary to introduce certain devices to ensure that a selector will reach any desired contact on its bank within the minimum interdigit pause. Some assistance in this direction can be obtained by the use of the "impulse chasing" principle (Fig. 565). With this scheme the main selecting mechanism is allowed to search over part of the bank *during* the reception of the impulse train from the subscriber's dial. If, for example, a subscriber dials the digit 4, it is possible to allow the main selector to hunt over all the bank contacts associated with the digit 1 immediately after receipt of the first impulse of the train. Similarly, the mechanism can be allowed to search over the trunks associated with digit 2 immediately it is clear that the trunk required is in the second or subsequent groups, i.e. immediately after receipt of the second impulse. The same conditions apply for subsequent impulses, and it is merely necessary to arrange the circuit so that the selector wipers do not "race" the incoming impulses. If we assume, for example, that it is necessary for the wipers to be stepped to the 200th contact (the most adverse case) in response to the dialling by the subscriber of the digit "0," there is a minimum period of, say, 1450 msec for the wipers to reach that contact (i.e. 1000 msec during reception of the impulses + 450 msec interdigit pause).

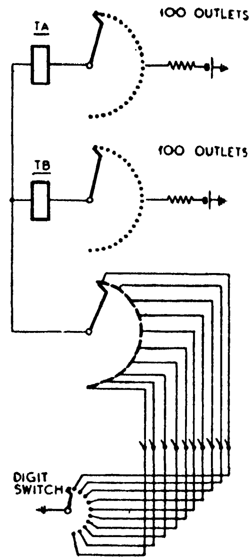


Fig. 566. Use of Dual Testing to Minimize Hunting Time

The conditions can be met by designing a switch with a hunting speed of $200/1{\cdot}45 = 131$ contacts per second. This is much more reasonable but, even so, the hunting speed is considerably higher than that required during rotary drive on a 2-motion selector. The adoption of the impulse chasing principle does, moreover, require selectors of the homing type, and the groups of trunks must be allocated to the bank contacts strictly in accordance with the digits which are required to give access to them, i.e. it is not possible to split the trunk groups or to add additional trunks at any convenient point on the bank. The loss of this facility in turn generally makes it somewhat difficult to alter the groupings of the bank contacts during the life of an exchange.

An alternative solution (or a method which can be made to augment a system of impulse chasing)

is to adopt multiple testing. Dual testing is already employed on 200-outlet group selectors of the 2-motion type. Under this scheme the outgoing trunks are arranged in pairs and two switching relays are necessary. The same scheme can readily be applied to a uniselector mechanism so that two trunks are tested during each rotary step of the mechanism (Fig. 566). Thus, by the use of dual testing it is possible to provide a selector with a total capacity of 200 outlets but, at the same time, to restrict the maximum number of contacts over which search is required to 100. This method of itself is usually insufficient to guarantee that a trunk to the next stage will be obtained during the most adverse conditions of intertrain pause. (Unless impulse chasing were also included in the scheme, it would require a mechanism which would hunt at 333 contacts per second.) The principle of multiple testing could be further developed by arranging for, say, 4 trunks to be tested concurrently at each rotary step. This would, however, require 4 separate switching relays individual to the selector circuit, and is generally not economical. Moreover, if more than 2 outlets are tested concurrently, it is difficult to design a circuit which will test the outlets in the correct order to meet the requirements of grading and which would also be fully safeguarded against double switching to 2 outlets at the same time.

Wiper switching methods can be used to augment a dual switching system in order to reduce the total number of steps to be made during the interdigit pause. This principle has already been described in earlier chapters in connexion with the 200-outlet final selector of the Post Office standard system. The selector can be designed so that the wipers rest on 4 trunks at each rotary step (Fig. 567). On any particular call any 2 of these 4 trunks can be preselected by a wiper switching relay which can be controlled either from the incoming impulse train or from a discriminating signal passed forward from the previous selector stage. By the adoption of wiper switching, in conjunction with dual testing on the selected pair of outlets, it is possible to design a system which will give a total of 200 outlets for the maximum of 50 rotary steps. If it is assumed that these 50 rotary steps must be made after the end-of-train switching signal, i.e. within an interdigit pause period of 300 msec, the system requires a mechanism which will drive at 166 contacts per second. This is a more reasonable requirement.

Ratchet and Pawl versus Motor Drive. We have seen that speed of search is a matter of some importance in any marker control uniselector system. In this connexion it is interesting to examine the various ways in which the wipers of such a unidirectional selector can be moved over the contact bank. One method is to provide a ratchet and pawl system actuated by an electromagnet under self-interrupted drive or machine generated impulses. Fig. 568 shows the velocity of the moving parts of a reverse-acting ratchet and pawl mechanism during three successive steps. When the electromagnet is energized, the armature gradually accelerates and reaches its maximum velocity at the end of its forward stroke. At this

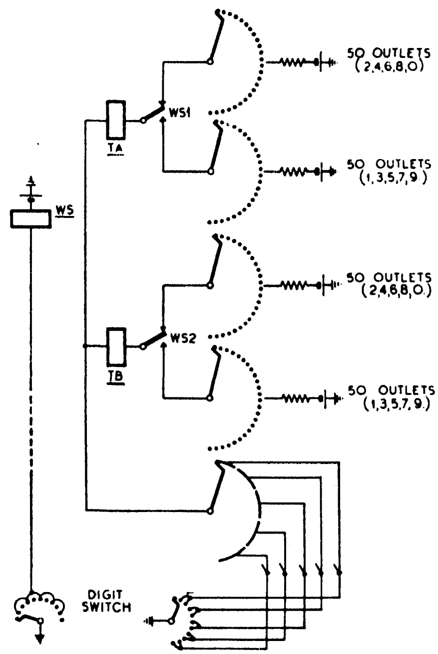


FIG. 567. COMBINATION OF WIPER SWITCHING AND DUAL TESTING TO MINIMIZE HUNTING TIME

point the armature movement is suddenly arrested, and the whole of the energy of the moving system must be dissipated in a very short space of time. During the release stroke, the armature again commences to accelerate but is slowed down when the pawl engages with the ratchet. The restoring armature must now take the full wiper load, and its velocity increases, at first gradually, and then more rapidly until a maximum speed is obtained when the armature hits its back stop. Here again, the whole of the energy of the moving system must be dissipated. The lower part of Fig. 568 shows very clearly how the wipers of a reverse-acting switch are subjected to periodical pulses of quickly accelerating movement, separated by very long

periods of no movement. The *mean* wiper velocity is, by comparison, very small indeed. (It may be of the order of one-twentieth of the instantaneous maximum velocity of the wipers at each step.)

An increase of hunting speed of such a selector can be obtained only by improving the acceleration of the armature, during either the forward or the reverse stroke (or both). Unfortunately, this involves very high peak velocities and a corresponding increase in the amount of energy to be dissipated at the end of each stroke. (The energy is proportional to the product of the mass and the *square* of the velocity.) High hunting speeds are tends to reduce the amount of wear on the mechanism. The motive power can be derived from a system of shafting common to a number of selectors, the selectors being connected to the drive by electromagnetic clutches as required. This method has been used extensively, and several systems of this type are described in the next chapter.

Any form of common drive system does, however, suffer from the disability that a failure of the drive system may produce a more or less serious breakdown. There are, therefore, some arguments for the provision of an individual motor to each selector, thereby obtaining the advantages of constant torque drive without the dependence upon a system of common shafting. The real problem here is to design a motor with the requisite power, small size and reasonable cost to justify its provision on the basis of one per selector.

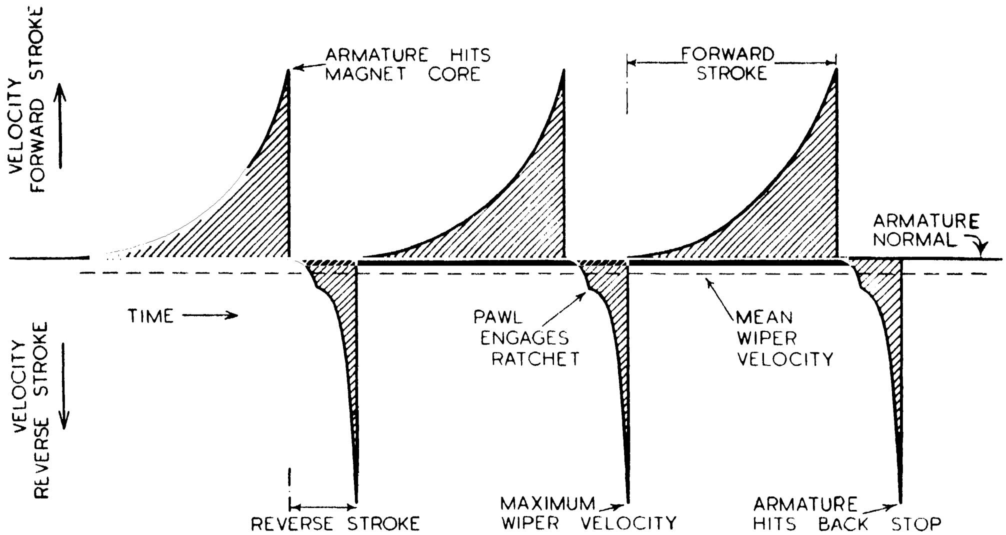


Fig. 568. Velocity Diagram of Ratchet and Pawl Type Mechanism (Diagrammatic)

particularly desirable on large capacity selectors (i.e. so that the wipers can search over a large number of bank contacts within a specified period). The larger the selector, the more massive becomes the mechanism. This further increases the total energy to be dissipated at the end of each stroke of the armature, and a point is soon reached where an increased rate of search can only be obtained at the expense of excessive wear and maintenance charges.

It is in practice very difficult to design a ratchet and pawl mechanism which will provide a hunting speed much in excess of 60 contacts per second.

Motor drive can be used as an alternative to a ratchet and pawl system on selectors which are not required to respond to dialled impulses. This type of drive is particularly suitable for marker control systems, and the constant torque obtainable from such a drive not only enables much higher wiper velocities to be obtained, but also tends to reduce the amount of wear on the mechanism.

THE R6 SYSTEM

The R6 System was developed by Compagnie Générale de Constructions Téléphoniques in collaboration with the Engineers of the French Telephone Administration. At the present time there are some 150 public exchanges ranging from 50 to 20 000 lines each, which together serve a total of some 300 000 lines. The principle of the R6 System has also been used in a number of semi-automatic exchanges and for Private Automatic Exchange work. The system has been adopted as the standard for provincial towns and rural areas throughout France, North Africa, and in the French Colonies.

Selector Mechanisms. The main selectors of the R6 System are of the unidirectional type with 51 rotary positions. A typical selector is illustrated in Fig. 569. The wipers are controlled via a ratchet and pawl system from a single coil electromagnet, interrupter contacts being provided to permit the selector to be operated under self-interrupted drive conditions. By a suitable arrangement of wipers, it is possible to obtain an availability of 50, 100, or exceptionally 200, as required. It will be noted that the bank levels are arranged in pairs, as on the British 2-motion selector. A similar, but smaller, edition of the uniselector is available for special purposes and has 25 rotary positions.

In addition to the main 51-point selectors, the R6 System also utilizes small rotary switches which are specially designed to receive the impulses from the subscriber's dial and to set up the appropriate marking conditions on the banks of the main selectors. Fig. 570 gives a general view of the "digit switch" used in the R6 System. This selector has a total of 11 rotary positions, and a 4-arm wiper assembly. It has been designed to mount along with the relays in the various control circuits. The switch is light in construction and will respond satisfactorily to impulses over a wide range of ratio and frequency (the operating time is of the order of 10 msec). Although the 11-point digit switch is usually stepped under the control of dial impulses, interrupter contacts are provided so that it is capable of homing under self-drive conditions.

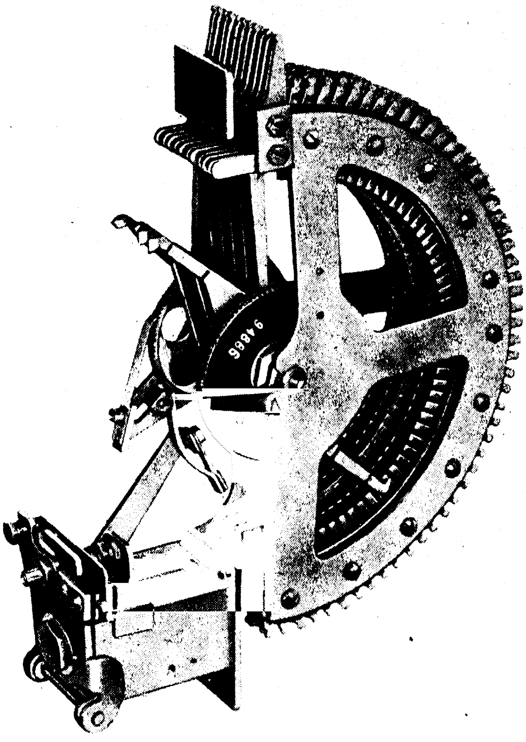


FIG. 569. 51-POINT R6 SELECTOR

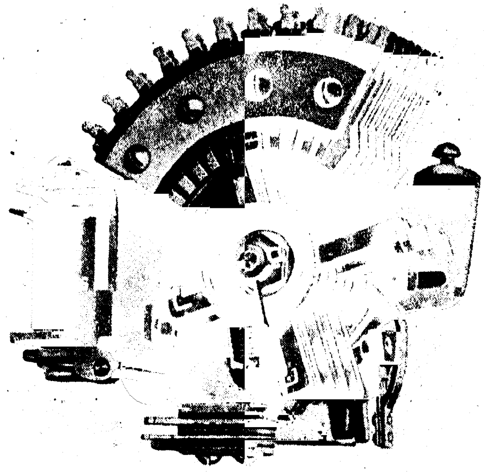


FIG. 570. IMPULSE COUNTING OR DIGIT SWITCH

Trunking Scheme. The R6 System employs marker control principles and utilizes common control circuits at each stage of selection. The system is designed for use either with or without registers in order to provide the most economical switching scheme in areas of various characteristics.

In general, each selector stage provides 100 outlets, the wipers being arranged alternately so that half of the wipers sweep over the bank during one half revolution, and the remaining wipers engage with the bank during the next half revolution. When the system is used in conjunction with registers, it is possible to adjust the intertrain pause from the registers to provide adequate time to enable the selectors to hunt, if necessary over the full 100 contacts of the bank. In these circumstances no special provision is made in the selector circuits to minimize the hunting time, and rotary search is not initiated until the end of the impulse train to the associated control. Where, on the other hand, registers are not justified it is necessary to minimize the maximum hunting time of the selectors, so that a trunk to the next stage will be seized during the minimum intertrain pause from the subscriber's dial. Under these conditions the

selector circuits are arranged to provide "impulse chasing" (q.v.) and give facilities for dual testing. This limitation of search to 50 contacts, coupled with the additional time obtainable by impulse chasing, enables the system to work satisfactorily with subscriber control of selection.

Fig. 571 gives a typical trunking scheme of an R6 System with registers. The lifting of the calling subscriber's receiver operates a relay in the line circuit, and this in turn marks the linefinder multiple and forwards a start signal to the common control circuit of the linefinder group. Access from the control circuit to the linefinder links is obtained via a distributor or allotter and, on receipt of a calling condition, the latter searches for a free linefinder/selector hunter link circuit. The register and its associated translator are common to a switch. At the appropriate time the register marks the required group on the banks of the 1st selector, and the latter is then caused to hunt for a free trunk in the selected group. The register is now extended to the common control circuit of the 2nd selector, and the second train of impulses is received on a digit switch in the latter. The position to which this switch is stepped determines the group marking on the banks of the 2nd selector, and the latter now searches for a free trunk in the selected group. The call thus proceeds in this way up to the final selector stage under the control of the impulse trains transmitted by the register. The final selector accepts the two final digits of the required subscriber's number and marks the exact contact on the bank of the selector to direct the call to the called subscriber.

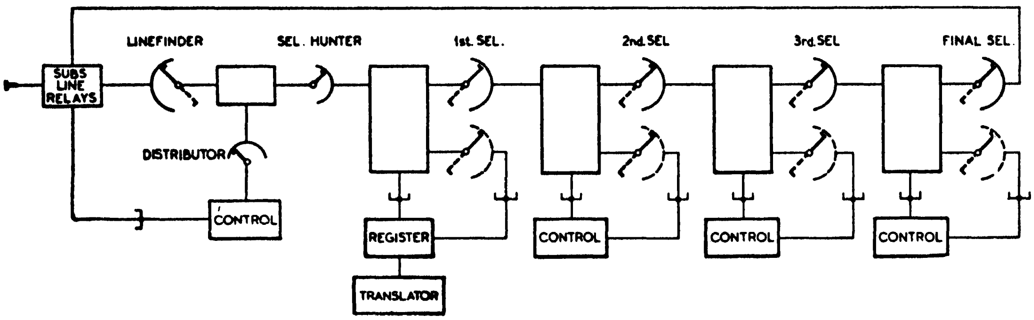


FIG. 571. GENERAL TRUNKING ARRANGEMENTS OF R6 SYSTEM WITH REGISTERS

number of 1st selector circuits and contain the controlling relays necessary to position the 1st selector. It is therefore necessary to engage all 1st selectors associated with one register whilst the register is in use for the setting up of a call. The circuit arrangements are such that, if all the outlets from a selector hunter bank are unavailable (either due to the absence of free 1st selectors or due to the engagement of the register), a busying condition is returned to the distributor banks so that the linefinder/selector hunter link circuit is automatically engaged.

When a free link circuit has been found, the selector hunter searches for a disengaged 1st selector which gives access to an available register. When the selector hunter switches, a signal is returned to the control circuit, and linefinder search is initiated. In due course the linefinder seizes the calling line and extends the caller via the 1st selector to the register. The impulse trains from the subscriber's dial are received in the latter on a number of uniselector mechanisms and, where translation facilities are required, the incoming impulse trains are utilized to position the translator

The trunking scheme of the non-register system is substantially similar to the arrangements shown in Fig. 571, except that the register and translator are replaced by a simple control circuit similar to the intermediate and final selector stages.

Main Circuit Features. Fig. 572 shows the simplified circuit arrangements of a typical group selector in the R6 System. (The relay designations, conventions, etc., have been adjusted to conform to British practice.)

The free condition of a selector circuit is a battery condition on the incoming P-wire obtained from the associated control circuit. If the selector is engaged, there is an earth condition on the P-wire so that the circuit tests busy to any searching selector of the previous rank. Similarly, if the associated control circuit is engaged (but the selector is free) earth is applied to the common point "0" from the selector which is engaging the control circuit. Under either condition, therefore, there is no battery potential and switching will not take place.

When a preceding selector switches to a free circuit, an earth seizure signal is applied to the

incoming — wire and thence via relay *K* to relay *ST* in the common control circuit. Both relays operate in series, relay *K* switching the various leads between the selector and the common control circuit, whilst relay *ST* operates relay *C* relay *TR* (via *TR*2 and **C3**), and ***TR*3** provides a local holding circuit for *TR* under the control of the digit switch interrupter contacts *Ddm*. After the operation of ***TR*3**, a holding circuit for relay *A* is provided via **C4** and *A***1**.

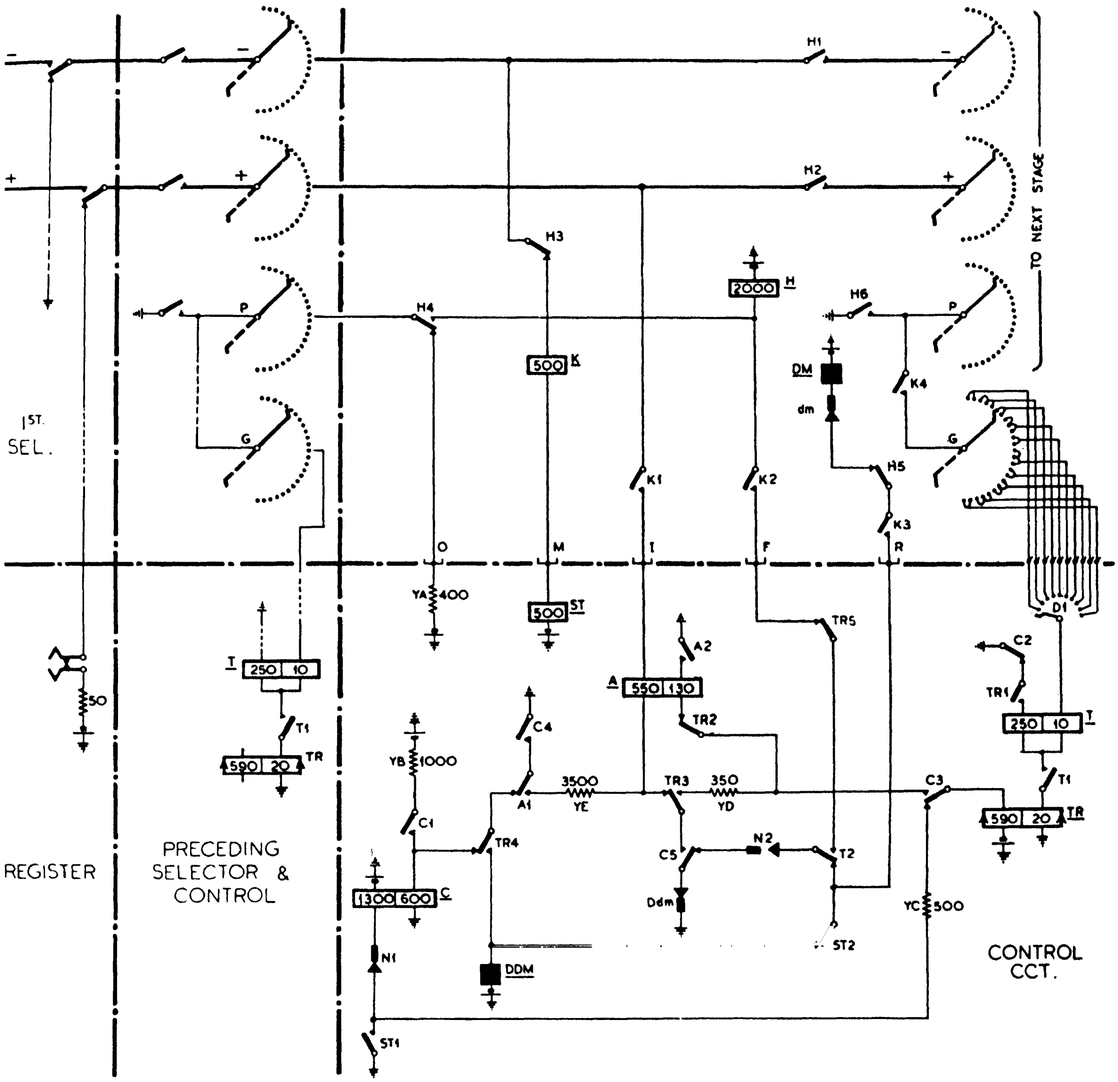


Fig. 572. Testing, Marking, Switching, Etc. Elements of R6 System with Registers

and thereby prepares the control circuit for impulsing.

Battery impulsing over the + wire is used throughout the R6 System. The first application of battery on the + wire prior to impulsing is extended via contact ***K*1**, the 550 Ω coil of relay *A*, *TR*3, **C5** to earth at the digit switch interrupter contacts *Ddm*. ***A*2** provides an operate circuit for

At the first break impulse, relay *A* releases and at *A*1 energizes the magnet of the digit switch (*DDM*). When the armature of this switch is fully operated, the interrupter contacts ***Ddm*** open, thereby releasing relay *TR*. *TR*4 now disconnects the magnet circuit and applies a short circuit to the 600 Ω coil of relay *C*. At the end of the impulse, relay *A* re-operates to the earth via *TR*3,

C5 and the *Ddm* contacts. **A2** re-operates *TR*, and ***TR*4** prepares the digit switch magnet in readiness for the second impulse. This process continues until the end of the impulse train, when relay *C* releases.

The release of *C*5 now completes a drive circuit

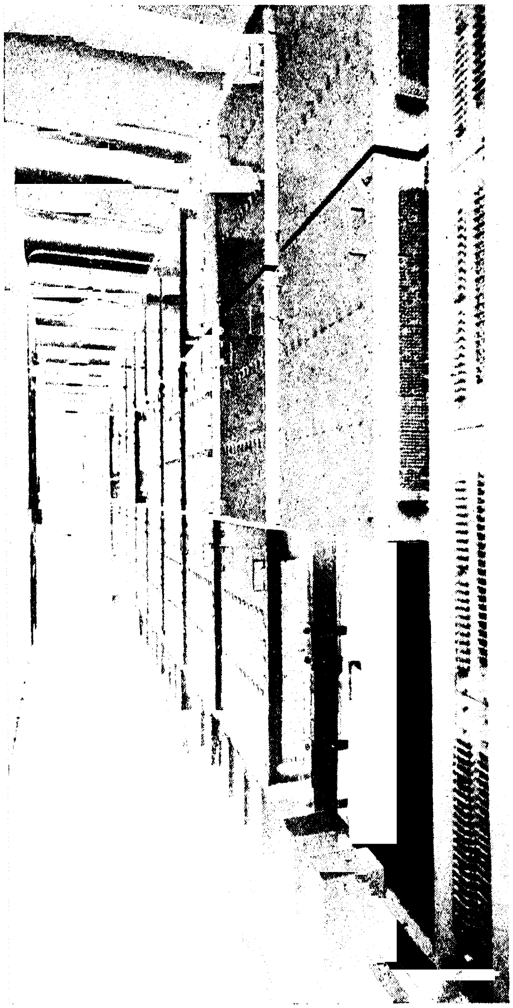


Fig. 573. General View of Selector Racks, R6 System
(Central D'Alger-Mustapha)

(via **N2**, **T2**, **K3**, etc.) to the driving magnet of the main selector. This switch operates under self-interrupted drive until the circuit is disconnected when a free outlet in the required group is found. The wipers (*D*1) of the digit switch extend the testing relay *T* to the appropriate group marking wires of the main selector. When the wipers of the selector reach this group, the *T* relay is connected via contact **K4** to the *P* wipers of the selector. If there is a free selector (with a free control) in the next stage, the battery potential on the *P*-wire operates relay *T* to the earth at *C*2. **T1** connects the 20 Ω winding of relay *TR* to the testing circuit, thereby providing a low resistance earth to engage the seized outlet. At the same time contact **T2** cuts the self-drive circuit of the main selector.

The release of *C*3 at the end of the incoming impulse train provides an operate circuit for relay *TR* via resistor *YC* to the earth at ***ST*1**. The windings of *TR* are differentially connected so that, under normal conditions, the current in the 20 Ω winding neutralizes the magnetic effect of the 590 Ω winding, thereby causing *TR* to release. *TR*5 now extends the earth from the *Ddm* contacts via **K2** to operate the switching relay *H* in the selector circuit. Various contacts of relay *H* switch through the speech conductors, engage the seized outlet, and disconnect the circuit of the coupling relay *K*. Contacts **K1**, **K2**, and **K3** isolate the selector from the control circuit, whilst the release of relay *ST* in the latter frees the control for use on a subsequent call.

If two selectors test to the same free outlet concurrently, both *T* relays operate to the battery condition on the *P*-wire. When the **T1** contacts close, however, the resultant current through the 20 Ω winding of each *TR* relay is approximately half of the normal value and is insufficient to cause release. Thus, under double testing conditions, the holding of the *TR* relays prevents the operation of the selector switching relay. (Note that, with this scheme, the safety margin against dual connexions is independent of variations in battery voltage.)

Equipment Details. The selectors of the R6 System are mounted in box type units which are provided with covers to exclude dust. The units are designed so that three standard units can be accommodated in each bay of the rack framework. Fig. 573 indicates the general appearance of the selector racks. The wiring of the selectors in each unit box is brought out to a series of connexion strips on the right-hand side of the unit, from which the circuits are cabled to other units, frames, etc. The common control circuits are in the form of relay sets which are jacked-in to channel type shelves at the bottom of the bay.

The subscribers' line relays are mounted in groups of 100, each group being enclosed in a separate box unit. The primary linefinders associated with the group, and the controlling relays for these linefinders, are similarly mounted in a separate unit. The same method of mounting is used throughout the exchange. In some selector stages

each unit accommodates three rows of selectors but, where it is necessary to associate relays with the selectors, each unit accommodates two rows of selectors and their associated relays.

THE BYPATH SYSTEM

The Bypath System was designed by Messrs. Standard Telephones and Cables Limited about 1930 and, although it has not been used extensively, two experimental exchanges were installed in this country (Acorn London, and Burton-on-Trent).

The Bypath System is essentially a marker control scheme based on the use of ratchet and pawl mechanisms with 51 contacts in each arc of the bank. The distinguishing feature of the system is the use of a system of high speed *bypaths*, by means of which the call is established stage by stage, the main conversational switches (the *paths*) being positioned by the marking conditions set up by the bypath circuits.

It is interesting to compare the arrangements of the Bypath System with those of the French R6 System. Both systems utilize mechanisms of similar size and with approximately the same hunting speed. The speed of the selectors is such that it is not possible to obtain complete search over 100 contacts during the pause between successive digits from the subscriber's dial. The problem is overcome in the R6 System by utilizing subscribers' registers or by arranging for impulse chasing and dual testing in the selector circuits. The adoption of impulse chasing requires the provision of homing facilities on the main selectors, whilst dual testing necessitates the use of two switching relays per selector.

The Bypath System employs similar principles for reducing the time of search for a free trunk, but the impulse chasing circuit and the dual testing circuit are located in the bypath circuit instead of in the main selector circuit. This in turn simplifies the design of the selector circuit, and it is possible to use simple non-homing selectors with a single switching relay, the complications necessary to provide impulse chasing and dual testing facilities being limited to the common circuits, which are few in number.

The use of a bypath system also has certain advantages in respect of the method of associating the selector with the common control (or bypath) circuit. Ordinarily (i.e. without the use of bypaths) the only practicable way of associating a selector with its common control is by means of a switching relay per selector. Association of the selector with its common control by means of a uniselector is generally inadmissible due to the additional time required to search for and seize a selector. The provision of a bypath circuit for establishing the call allows a theoretical unlimited time to search for a main conversational switch and for the latter to take over the connexion from the bypath. It is therefore possible to obtain access to the main selector via a coupling uniselector provided on the basis of one per control or bypath circuit. This feature of the Bypath System obviates the necessity of one of the switching relays in the main path circuit and, perhaps what is more important, it enables the selectors to be arranged in larger common control groups, each group being served by a suitable number of bypaths. (With relay association, one

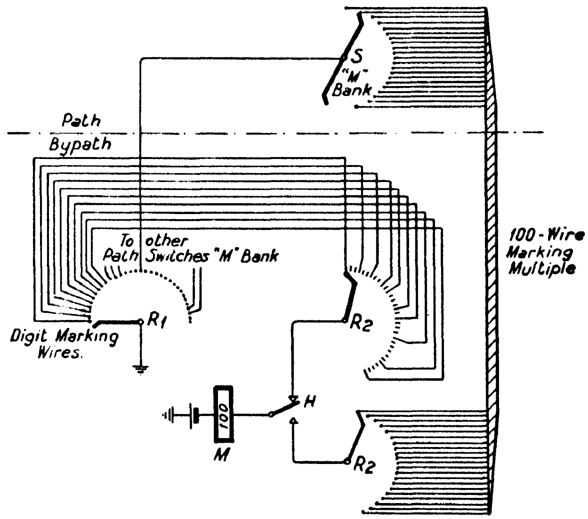


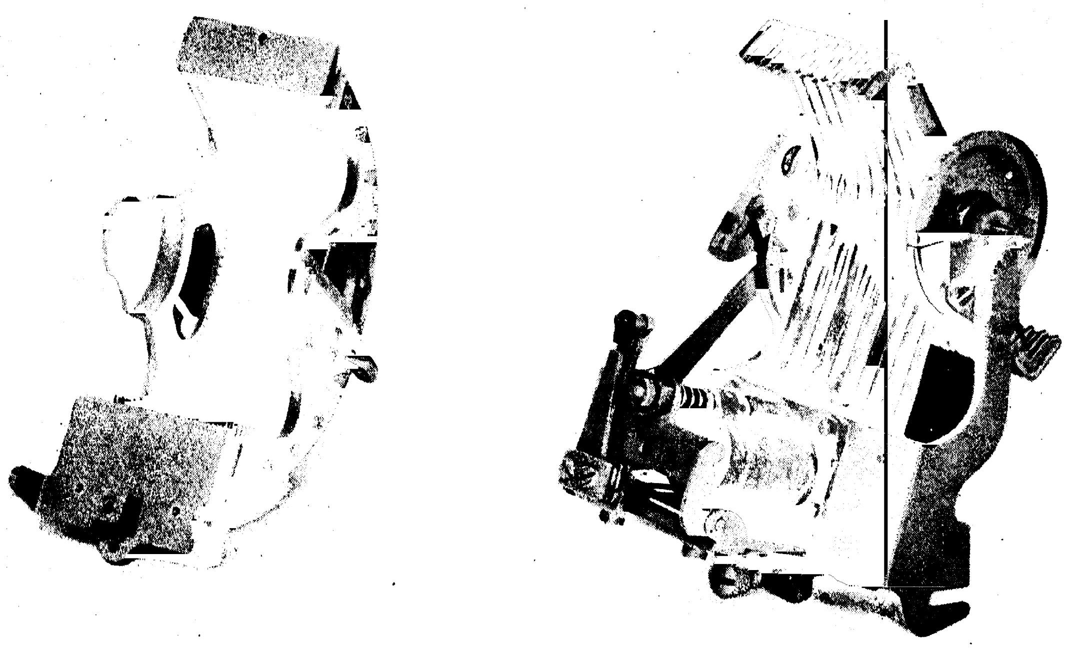
FIG. 574. METHOD OF POSITIONING SELECTORS OF BYPATH SYSTEM

switching relay per control circuit would be required in each selector.) Some further economies are made in the Bypath System by using one switch both for impulse reception and then later for finding a disengaged path circuit.

Method of Positioning Selectors. The method of positioning the main path switches is illustrated in Fig. 574. The bypath contains two 50-point uniselector mechanisms known as the $R1$ and $R2$ switches. The impulses dialled by the calling subscriber are received in the bypath circuit and step the $R1$ switch. The $R2$ switch then hunts for the corresponding position on its bank marked by the wiper of $R1$. When this position is reached, the $R2$ switch is at the beginning of the required group of trunks. The $R2$ switch now commences to hunt for a free trunk in the selected group. When a free outlet is found, a separate wiper of the $R2$ switch marks the appropriate bank contact of the speaking path switch (S) multiple.

The $R1$ switch now searches for and seizes a disengaged "path" selector. The drive is completed for the latter, and, when the marked contact is reached, relay M operates to release the bypath. The calling party is now extended through the main path switch to the bypath of the next switching stage.

Bypath Mechanism. Fig. 575 shows the selector which is used throughout the Bypath system. It is a mechanism of the uniselector type operated through a reverse-acting ratchet and pawl system from a twin coil electromagnet. The bank has 51 contacts per arc, and the switch frame will accommodate up to 10 wipers. It is possible to obtain a total of 102 effective outlets by arranging the wipers as two sets, so that they can search successively over different sections of the bank. The mechanism can be readily withdrawn from the bank by lifting the latch springs and withdrawing a single fixing screw. The wiper arms of this switch are comparatively long and, in order to obtain the necessary rigidity, they are of I cross-section. The wiper tips are long and flexible and are divided so that there are four independent points at which pressure is exerted on the bank contact. This feature together with the use of a special spring suspension for the switch helps to minimize microphonic noise.



(a) Bank (b) Mechanism

Fig. 575. Bypath Uniselector

Trunking Arrangements, 4-digit Exchange. Fig. 576 shows the progress of a call on a 4-digit Bypath system. The subscribers' lines are arranged in groups of 100, each group being served by a number of double-hunting first linefinder switches. The exchange is divided into units of 5000 lines, and all the first path circuits in each unit are directly connected to 50-point second linefinders. Each second linefinder has access to at least one first linefinder of every subscribers' group. Thus the first stage path has access to every line in the 5000-line unit.

When a calling subscriber lifts his receiver, half of the available first bypaths of the 5000-line unit are seized momentarily. The group finder switch (GF) in each bypath hunts for the particular group of 100 lines from which the call originates. When two first bypaths have found this group, the remaining bypaths are released. A test is now made to prove that a trunk is available between the first main paths associated with each bypath and the selected group of first linefinders. Each

of the two successful bypaths causes a first linefinder in the selected subscriber's group to hunt for the calling line (i.e. two first linefinders hunt simultaneously). When the line has been found by one of the linefinders, the remaining linefinder and its associated bypath are released.

The line is now extended through the first linefinder and the group finder selectors to the impulse accepting relay in the first bypath. Dial tone is returned to the caller at this stage. It has been seen that each bypath has two other selectors known as the $R1$ and $R2$ switches. $R1$ responds to the impulses from the dial and pilots the second switch ($R2$) to the beginning of the required group. $R2$ now searches in that group for an idle second stage path whose bypath is also free. At the same time $R1$ hunts for an idle first stage path. When $R2$ has found a free trunk between the first and second stages, the speaking pair is extended through to the second stage bypath. The seizure of a path by $R1$ causes a second linefinder associated with that path to rotate to the position marked by the group finder in the bypath. At the same time the first path selector rotates to the position marked by $R2$. Whilst these switches are hunting, a temporary path is provided to feed the impulses of the second digit through the first linefinder, the group finder, $R2$ selector to the impulsing relay in the second stage bypath.

The second bypath is similar to the bypath of the first stage and has $R1$ and $R2$ selector switches. $R1$ responds to the second digit, thereby piloting $R2$ to the correct group. $R2$ then searches for an idle trunk to the next and final stage, whilst $R1$ hunts for the marked second stage path. When communication has thus been established between the second stage path and bypath, the first stage bypath is released and is available for another call.

The call proceeds in the above manner from stage to stage, but the penultimate bypath remains in circuit until the required line is tested. This is necessary in order that the bypath can signal to the penultimate path whether the line is free or busy. Immediately this signal is conveyed, the penultimate and final bypaths are released and the connexion is established over the main path switches.

In the final stage the $R1$ switch steps to the tens digit and $R2$ finds the marked condition. When this has been done, $R2$ becomes associated with the reception of the units digit and steps forward to mark the required subscriber's line on the bank of the final stage S switch.

The penultimate path circuit contains the transmission bridge, and all the main path switches are held from this point.

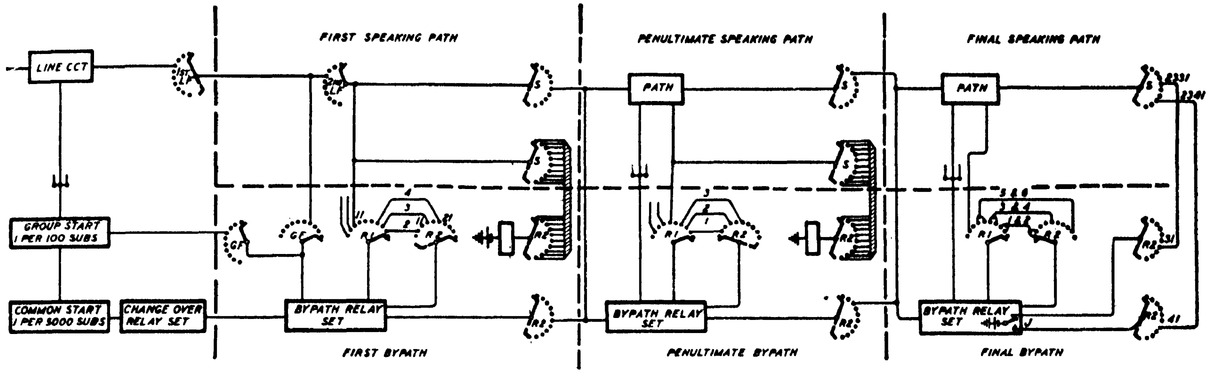


FIG. 576. OUTLINE OF TRUNKING SCHEME, 4-DIGIT BYPATH EXCHANGE

Translator Scheme. The bypath system has been developed also to meet the demands of large exchanges in metropolitan areas where complex junction conditions exist. Fig. 577 gives a trunking scheme for a 7-digit bypath exchange. Translators are provided to determine the correct routing in response to the dialling of the code digits by the subscriber, whilst the numerical portion of the required number is temporarily stored in registers. An interesting feature of the system is that where a call is to be routed over a direct junction neither translators nor registers are required. If, however, the direct junction should be engaged, then the translator is arranged to pulse out the trains required for the alternative routing via a tandem or sub-tandem centre.

The initial or A digit is received by the first code stage which is similar to the first stage of the 4-digit scheme already described. The B and C digits are received by the second code stage, where the B digit steps the $R1$ switch and $R3$

automatically steps to the marked contact. The pulsing-in circuit is transferred to $R3$, and this switch steps forward in response to the C digit. The $R3$ switch now stands at a position corresponding to the code digits dialled, whilst $R1$ hunts for a second code path. The position of the $R3$ switch marks the bank of $R2$ at the commencement of the direct junction group required. The $R2$ switch rotates to this position and commences hunting for a free junction in that group. When a free junction is found, $R2$ marks the immediately after the receipt of the C digit. The numerical digits are received by the second code stage and are repeated over a pulse wire to the register. Should a call be routed direct, the register is released immediately the junction has been seized.

It has been seen that, when the B and C digits have been received, the $R3$ selector of the second code bypath is standing on a set of bank contacts corresponding to the code digits dialled. Other wipers of this switch are used to mark a translator

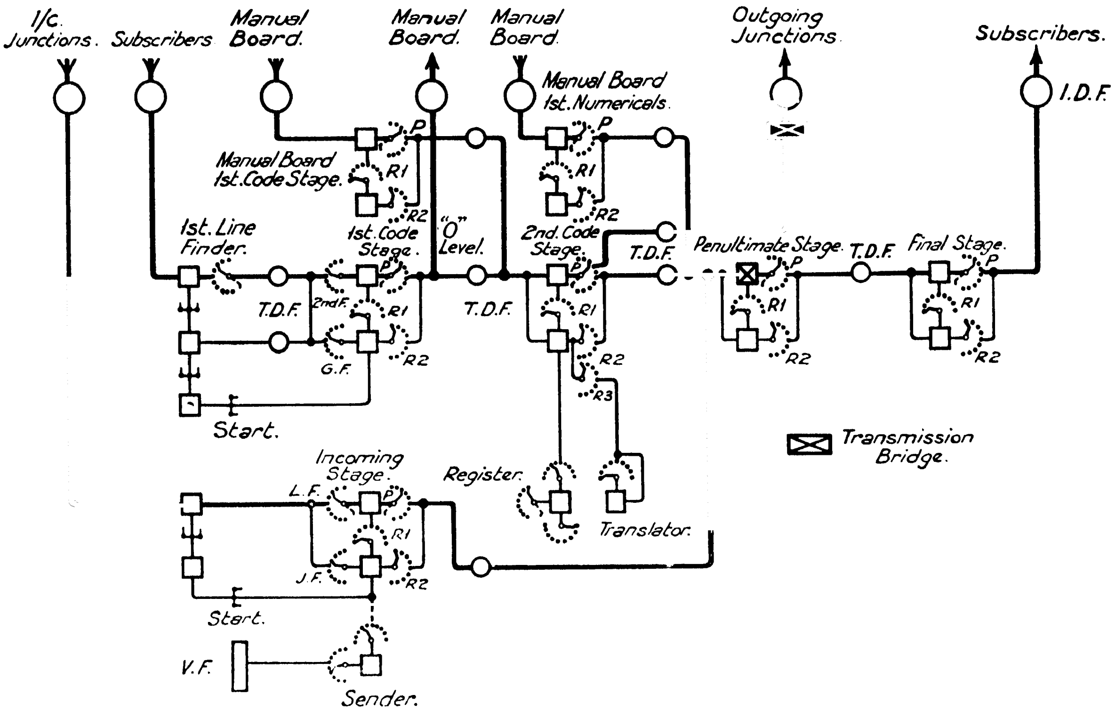


FIG. 577. 7-DIGIT BYPATH SYSTEM WITH TRANSLATORS

contact and the second code stage speaking path hunts for the marking condition.

Should congestion occur on the direct group of junctions, it is necessary to route the call via a tandem or sub-tandem centre. At the end of each junction group on the $R2$ switch is a bank contact marking the "end of group" position. When all junctions are engaged, the switch steps to this position. If alternative routing is required, a marking earth is extended to the bank contact of $R2$ which corresponds to the commencement of the alternative junction group. The $R2$ switch can now hunt forward for this marked contact and, on reaching it, commences to search for a free junction to the tandem exchange.

A free register is associated with the bypath which is permanently wired to give the translation required should alternative routing be necessary. The translator returns to the register the correct signals for the transmission of the translated routing digits. After transmission of the translation, the translator is released and becomes available for use on another call. The register then commences pulsing out the numerical digits.

Special Facilities. A number of special facilities were introduced in the design of the Bypath system:

(*a*) The system provides for trunk offering over the normal switches.

(*b*) The bypaths of all stages are in pairs, which are arranged so that, in the event of a bypath becoming faulty, its partner takes

over the control of the associated main path switches.

(c) The register is capable of sending out coded pulses when a call is to be routed to a C.C.I. manual exchange.

(d) The penultimate path, which controls the application of ringing, is arranged to transmit a short initial period of ringing current before switching to the normal interrupted ringing supply. This helps to prevent a P.B.X. operator from seizing an exchange line after it has been taken by a final selector.

SIEMENS NO. 17 SYSTEM

The Siemens No. 17 System was originally designed in 1933 and has recently been re-introduced with a number of detailed improvements. The system is essentially a marker control uniselector scheme, with common control circuits, the selectors being positioned stage-by-stage under the control of the calling subscriber's dial (Fig. 578). Registers are not normally employed. The distinguishing feature of the S.17 System is the use of mechanisms of large capacity and with an exceptionally high speed of search. This in turn has made possible the adoption of a straightforward stage-by-stage selection scheme without the need for complicated devices to keep the time of search within the minimum pause period between digits. The large capacity of the selector makes it possible to adopt very economical trunking schemes, and the efficiency of the system is still further enhanced by the adoption of a simple method of combining routes through the exchange.

The system has been designed to operate at the standard voltage of 50 with the usual limits (46–52 V). The usual British Post Office tones are provided.

The Motor Uniselector. The main switching mechanism of the S.17 System is the motor uniselector which has already been described in Chapter III. (The selector is illustrated in Figs. 88 to 91.) This selector, which was originally designed for the S.17 System, provides 16 arcs each of 51 bank contacts. By a suitable arrangement of wipers it is possible to obtain a total of 200 or 250 outlets, depending upon the number of wires required per circuit. Rotation of the wipers is obtained via a system of reduction gears from a simple and inexpensive d.c. motor individual to each selector. The speed of rotation is such that the wipers move over the bank contacts at the rate of 200 contacts per second.

The selector banks are multipled together by machine made flat ribbon cable which incorporates a system of transpositions on the speech conductors between each bank. This method of construction minimizes the liability to cross-talk, and the method of locating the cable is such that there is ready access to the contact bank terminals for maintenance.

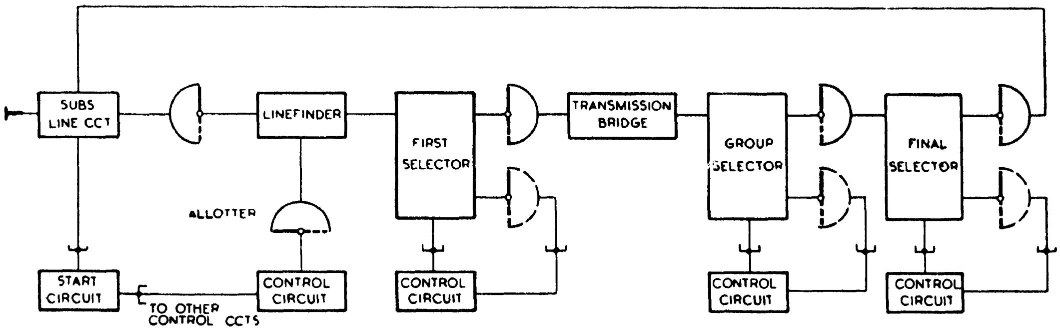


FIG. 578. MAIN TRUNKING ARRANGEMENTS OF SIEMENS NO. 17 SYSTEM

The Digit Switch. The impulse trains from the subscriber's dial are made to operate a digit switch in the appropriate control circuit. This digit switch has been specially designed to give a good performance over a wide range of impulsing conditions, and provides a large number of wipers for marking purposes. The complete switch is small in size, and has been designed to mount along with the relays of the jacked-in control sets.

Fig. 579 gives three views of the switch mechanism and bank. The mechanism is readily removable from the bank assembly for adjustment and replacement purposes.

The maximum bank size provides 8 arcs, each of 12 contacts (i.e. 10 working contacts, plus 1 home and 1 last contact.) (There is a 9th dummy arc for cross-connecting purposes.)

The wipers comprise pairs of quadruple-ended nickel silver blades, which engage with bank contacts of the same material. There are no feeder brushes in the accepted sense, but the electrical

connexions to the wipers are led via solid sectors at each end of every arc of contacts. The arrangements are such that the lower sector in each case acts as a feeder to segments 6–10 (plus the last contact), and the upper as a feeder to the home position plus contacts 1–5. The rear of the bank

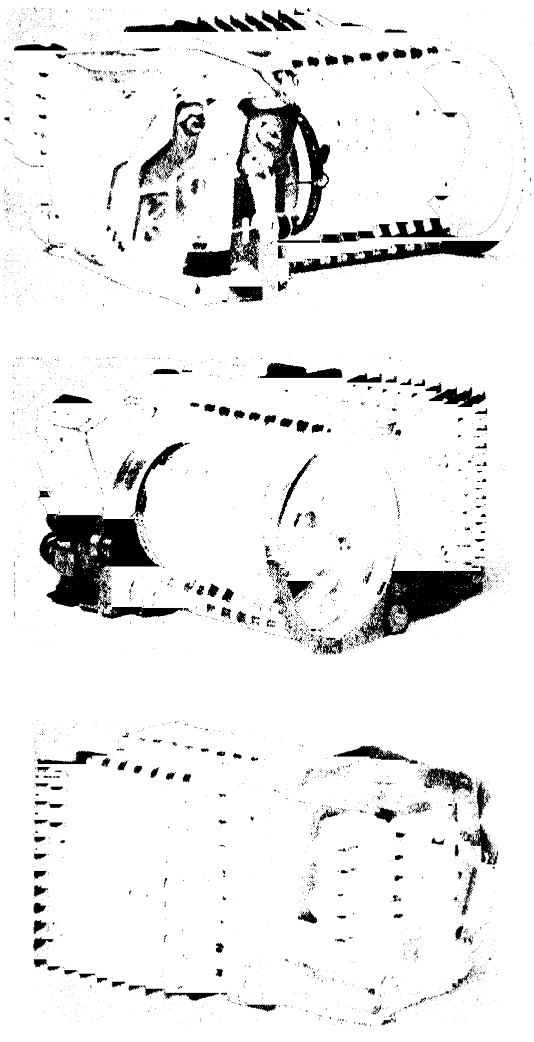


FIG. 579. THE DIGIT SWITCH

presents a flat wiring field, and the complete unit fits into the space normally occupied by four 3000 type relays.

The frame of the mechanism is an aluminium alloy die-casting on which the various parts are mounted. The switch is controlled from a single coil electromagnet, which steps the wiper assembly via a reverse-acting ratchet and pawl system. The driving pawl itself is of very small mass, and the driving pressure is imparted by a flat steel spring. Interrupter springs are fitted to permit self-drive, facilities being provided for accurate positioning of the interrupter springs by an adjusting screw.

The small mass of the armature and driving pawl enables the switch to operate satisfactorily under adverse impulse conditions. The switch self-drives at from 60–70 steps per second at 50 V.

Relays. The No. 17 System utilizes standard P.O. 3000 type relays for all purposes, except drive

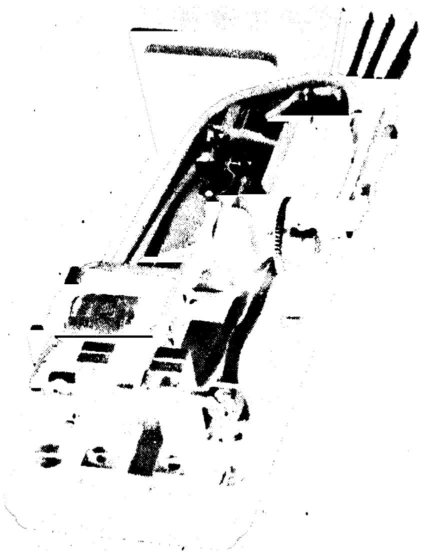


FIG. 580. HIGH SPEED RELAY (SINGLE CHANGEOVER CONTACT)

cutting and impulse repetition. The motor uniselector drives at such a speed that the wipers are in contact with a particular bank segment for something less than 3 msec. During this time the drive cutting relay must operate, and the movement of the mechanism must be arrested. The ordinary type of general purpose relay is insufficiently fast in operation, and hence a special high speed relay is used for drive cutting purposes. The relay is illustrated in Fig. 580 and has previously been described in Vol. I. It is provided with a single changeover contact unit and, in the drive cutting circuit of the No. 17 System, the relay opens its break contact within $\frac{1}{2}$ msec after the closure of the magnet circuit. The make contact closes within 1 msec of the closure of the circuit. In a relay of this type, ease of adjustment and adequate contact pressures are matters of prime

importance. The drive cutting relay is designed to give contact pressures of the order of 17 g, and the relay is easy to adjust for both contact openings and pressures.

Fig. 581 shows another type of high speed relay used in the No. 17 System for impulse repetition purposes. The relay provides two changeover contact units, and the moving contacts are connected directly to two separate armatures, both of which are controlled from the same electromagnet system. The armatures are insulated from the moving contacts by mica sheet, whilst the fixed contacts are readily adjustable (in relation to the moving spring) by adjusting the bow of screw controlled positioning springs. The break contact pressure is applied by two screws (one per changeover) which exert pressure on the two armatures, the fulcrum line of the latter being the rear pole face of the magnet core. The coils themselves are of a larger type than those on the single changeover high speed relay in order to obtain a higher sensitivity under junction impulsing conditions. The frame of the relay is a die-casting to give the required rigidity.

Common Controls. Wherever possible, the relays, digit switches, etc., necessary to position the motor uniselectors are placed in control relay sets which are common to a number of selectors.

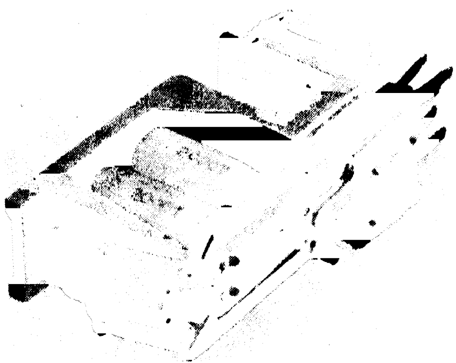


Fig. 581. High Speed Relay with Two Changeover Units

The number of selectors associated with each control circuit is determined primarily by the time for which the control set is in use during the setting up of each call. The normal provision is:

1st selectors: one control set per 6 selectors.

Intermediate group selectors: one control set per 9 selectors.

Final selectors: one control set per 3 selectors.

The occupancy time of the 1st selector control is somewhat greater than that of the control set associated with intermediate group selectors, due to the time which may elapse before a subscriber commences dialling. At the final selector stage, the control set is required to receive two digits,

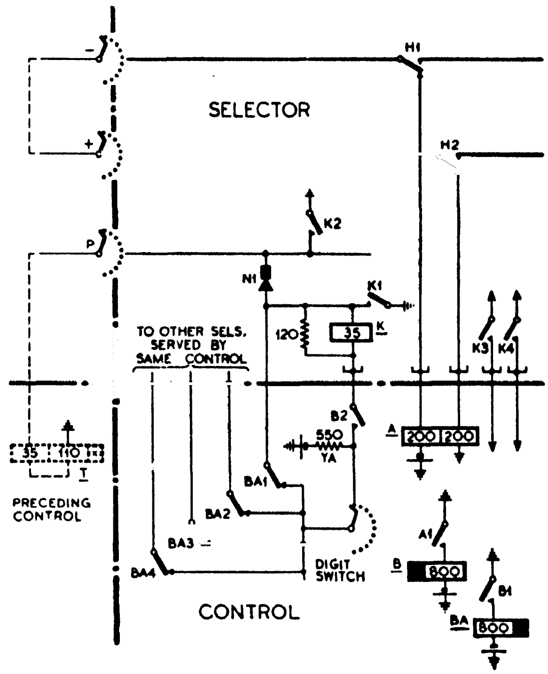


Fig. 582. Method of Associating Selector with Common Control Circuit

and hence is occupied for a greater period than the control sets of preceding stages.

Incoming selectors are an exception to the general use of common controls, and in these circumstances an individual control circuit is provided per selector.

Fig. 582 shows the method of coupling a selector to its control circuit. The free condition is a 550 Ω battery on the incoming P-wire of a selector. This battery is supplied from the common control circuit only if the control circuit is disengaged and the selector itself is normal. Under these conditions, relay T operates via $N1$, $BA1$, the first contact of the digit switch, to battery via YA. The operation of T extends the caller's loop to operate relay A in the control circuit of the selector seized, and A in turn operates B and BA. $B2$ completes a circuit for the K relay, and the latter holds via its own contact **K1** to the 550 Ω battery in the control set.

The contacts of K switch through the remaining wires between the control set and the selector

which has been taken into use. When the selector is positioned in accordance with the digits dialled, relay *H* operates and, by disconnecting *A*, allows relays *B*, *BA*, and *K* to restore, thereby dissociating the circuit from the common control.

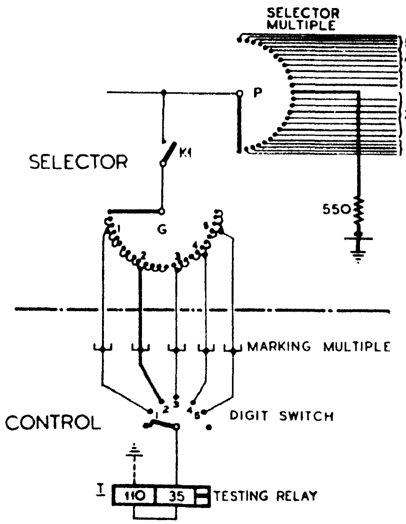


FIG. 583. METHOD OF MARKING REQUIRED GROUP OF TRUNKS (GROUP SELECTOR)

It should be noted that all selectors served by one common control are engaged from the moment that the testing relay is applied to the incoming *P*-wire of one of the selectors until all the relays and the digit switch in the control restore to normal.

Group Marking and Selecting. Fig. 583 shows how the required group of outgoing trunks is selected. Generally speaking, all the circuits of one group are arranged on consecutive bank contacts, but this is not necessarily so, and the circuits of any one group can, if desired, be intermixed with the circuits of other groups at any point on the switch bank. One arc (*G*) of the motor uniselector is set aside for applying the group marking condition. In Fig. 583 it is assumed that contacts 2–6 of the switch accommodate the circuits of group 1, whilst the circuits of group 2 are arranged on outlets 7–14. Groups 3, 4, and 5 are arranged on subsequent groups of bank contacts. All the switch positions which are taken up by the circuits in any one group are commoned together on the *G* bank, and the common is taken to the appropriate contact of the digit switch in the control circuit. The digit switch is positioned by the impulse train from the calling subscriber, and extends the testing relay to the marking commons of the appropriate outgoing group of the selector multiple. The start circuit of the motor uniselector is now completed, and the *P* wiper searches for the free battery condition. The testing circuit is completed only when the *P* wiper rests on a bank contact of a disengaged selector in the required group—all other battery conditions on the *P*-wire being isolated from the testing relay by the strappings on the *G* arc.

Testing and Switching. Fig. 584 shows the testing element in somewhat greater detail. The restoration of contact *C*1 at the end of impulsing completes the drive circuit for the motor uniselector and, at the same time, applies earth to the testing relay (*T*). The *T* relay is applied to the *P* wiper whilst the latter is passing over outlets in the required group and, when the free condition is encountered, relay *T* operates. **T1** short-circuits the 110 Ω coil of the *T* relay and the metal rectifier to reduce the potential on the *P*-wire and thereby to guard the circuit which has been seized. At the same time **T1** disconnects the circuit to the latch magnet of the motor uniselector to cut the drive. The operation of *T*1 removes the short circuit from relay *TA* which now operates in series with the latch magnet, but (due to the high initial impedance of the relay) does not prevent the release of the magnet. **TA2** applies earth to the *H* relay in the selector circuit, which now operates to complete the switching. When the lines are

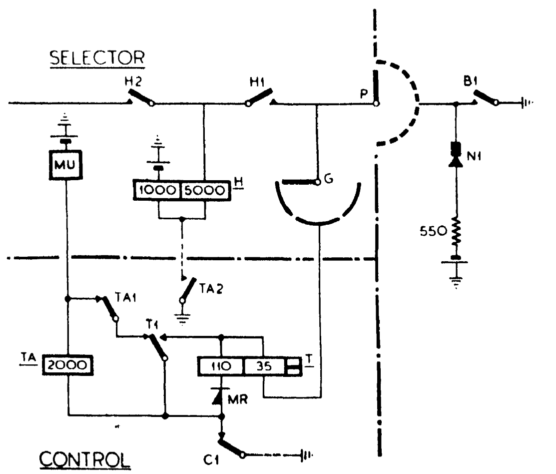


FIG. 584. TESTING AND SWITCHING ELEMENT

extended to the seized circuit, earth is returned on the *P*-wire, which releases relay *T* and the control circuit. The selector is now controlled by earth on the *P*-wire which holds relay *H* over both coils in series. It will be noted that the switching relay (*H*) is of high resistance (6000 Ω) in order to secure a high factor of safety against the *P*-wire

testing free to searching selectors during the interval between the removal of the earth from the P-wire and the complete release of relay H.

Rectifier MR is included in the initial operating circuit of relay T to increase the margin of safety against double connexions. It was seen in Vol. I that a metal rectifier has a high impedance when the voltage across it is small. If two T relays are applied simultaneously to the same disengaged trunk, the potential across the metal rectifier is reduced. Under these conditions, the impedance of the rectifier is increased with the result that the current in each T relay is materially less than the value which would be obtained if the rectifiers were omitted.

Wiper Switching and Positioning. The motor switch provides for a maximum of 16 wipers which are usually sub-divided into four groups, each of 3 or 4 wipers (—, +, P, and sometimes M-wires). This provides for a total of 200 outgoing trunks, which are divided into four sections, each of 50 trunks. Incoming selectors are provided with five groups, each of 3 wipers so that a total of 250 trunks is obtained.

On most selectors single-ended wipers are arranged in alternate groups, as shown in Fig. 585. The wipers are commoned together in pairs, and a wiper switching relay enables the appropriate part of the bank to be selected. On linefinders and final

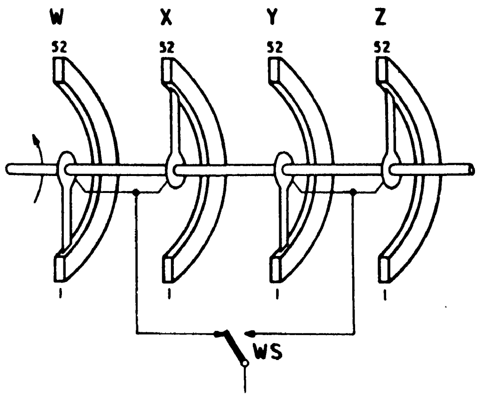


FIG. 585. USE OF SINGLE-ENDED WIPERS TO PROVIDE TWO GROUPS EACH OF 100 TRUNKS
(Group selection under control of WS relay)

selectors, the first 100 outlets are connected to arcs W and X, whilst the second 100 outlets are connected to the two remaining sections of the bank (Y and Z). The circuit is arranged so that the correct group of 100 outlets is predetermined by the operation or non-operation of relay WS. The required line within the selected group of 100 is obtained by allowing the switch to make a search for one complete revolution, i.e. so that wipers W and X search consecutively over their respective banks.

On 1st and intermediate group selectors, the

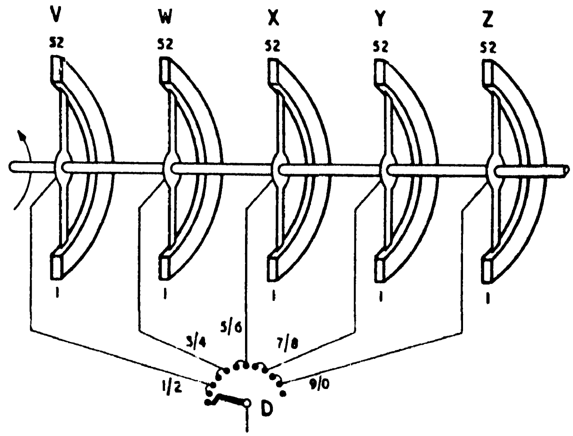


FIG. 586. METHOD OF WIPER SELECTION ON INCOMING SELECTORS
(Note that 250 trunks are obtainable by this arrangement)

wipers are arranged in a similar way, but, in order to keep the hunting time within the period of the interdigit pause, the search is restricted to a maximum of 50 outlets. When the required group of outlets has been determined, relay WS selects the appropriate half of the bank, but the required group of 50 within this half is selected by prepositioning the wipers. For example, if it is assumed that relay WS is normal, and the wipers are in the position shown in Fig. 585, it is clear that search will be made over arc W during the first half revolution of the switch. If the required group is in, say, arc Z, then the outlets of this group can be tested during one half revolution of the switch if relay WS is operated and if the wipers are rotated through an angle of 180° before search is commenced. The two features of wiper switching and wiper positioning enable the search to be restricted to 50 outlets at all group selection stages.

Fig. 586 shows the method of wiper selection adopted on incoming selectors. In this case the appropriate part of the bank is selected by the digit switch, e.g. section V accommodates the outgoing trunks for levels 1 and 2, section W accommodates the outgoing trunks for levels 3 and 4, and so on.

Pairing. It has been seen that one of the features of the No. 17 System is the concentration of traffic into a small number of individual groups. This object is achieved by arranging that each group

of outlets serves, not one numeral of the digits concerned, as is usual, but two digits. The principle is known as pairing, and is illustrated in Fig. 587. Each final selector serves a group of 200 lines. When an outlet from a group selector is seized, the engagement of the final selector is accompanied by a momentary signal to give group discrimination. Thus, by the use of this discriminating signal, only one group of circuits is required from the pre-final selector stage to serve two groups each of 100 subscribers' lines. The adoption of the pairing principle between the last stage of group selection and the final selector should not be confused with the arrangements in the Post Office standard system. In the latter, 200-line final selectors are employed, but access to each of the two groups of 100 lines is obtained from different levels of the pre-final selector, i.e. although one common group of final selectors is used to serve 200 lines, there are nevertheless two separate and distinct groups of circuits from the last group selector stage. In Fig. 587 the group selector is also a 200-outlet mechanism, so that, for an average availability of 20, the selector can give access to ten separate final selector groups. As each final selector group has access to 200 lines, the group selector can therefore be made to search a total of 2000 lines. (The last group selector stage of the standard Strowger System gives access to 1000 lines with the same availability.) The increased capacity of the group selector stage due to the use of the pairing principle enables (in some cases) one stage of group selection to be eliminated.

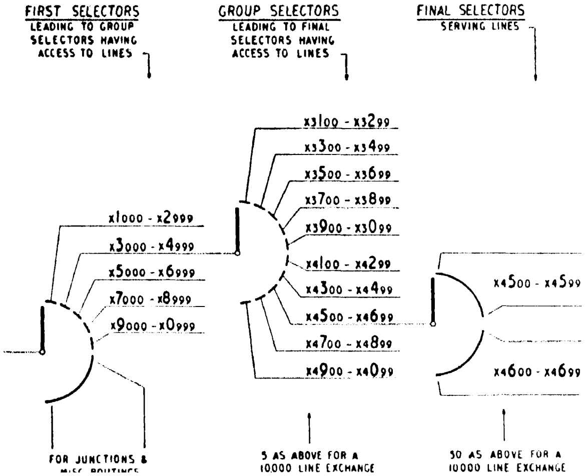


FIG. 587. TYPICAL TRUNKING ARRANGEMENTS FOR A 10 000-LINE EXCHANGE SHOWING METHOD OF COMBINING ROUTES BETWEEN SELECTOR STAGES

The trunks between the 1st selectors and the group selectors are also paired. Thus, in Fig. 587 there is one group of circuits to carry the traffic for both the third and fourth thousand lines. By this means, in a 10 000-line exchange, the total number of groups from the 1st selectors to 2nd selectors is reduced to 5 and, if the average availability is 20, these 5 groups absorb only half of the 200 outlets available at the 1st selector stage. The remaining 100 outlets are thus available for outgoing junctions and miscellaneous routings.

The circuit of the 1st selector can be arranged to take the two initial digits. The first digit (marked with an *X* in Fig. 587) can be used to determine that the call is local, and the second digit to select the appropriate "level." The progress of a call can best be explained by assuming that the local exchange has a 5-digit numbering scheme and provides a capacity for 10 000 lines. On receipt of the first digit, the 1st selector control circuit determines that the call is local, and it suspends selector search until the second digit has been received. If the second digit is, say, 4, the 1st selector searches for a group selector in the 3000–4999 group and, at the same time, passes forward a signal to indicate that selection is to proceed via that part of the group selector banks which gives access to lines 4000–4999. The hundreds numeral (say, 5) is then dialled into the group selector control circuit, and results in the seizure of a final selector having

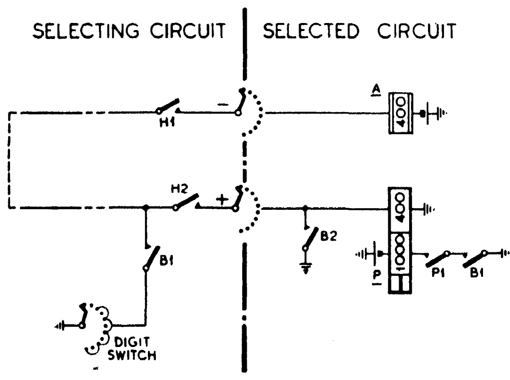


FIG. 588. PRINCIPLE OF THE DIFFERENTIATING SIGNAL ON "PAIRED" ROUTES

access to lines 4500–4699. At the moment of seizure, a signal is passed forward to the final selector to indicate that selection is to take place in the part of the bank which serves lines 4500–4599. The final selector control circuit records the two final digits to establish the connexion to the required subscriber.

The principle of pairing is also applied to outgoing junction groups. By this means it is plain that material plant economies can be effected owing to the higher traffic carrying capacity per circuit which can be obtained due to the larger groups formed by pairing.

To summarize:

(*a*) Pairing halves the number of traffic routes through the exchange (and over the junctions), and thereby produces larger groups which have a higher traffic carrying capacity (per circuit) than the smaller groups available if pairing were not adopted.

(*b*) The reduction in the number of groups can be used to increase the availability of each group, thereby further increasing the trunking efficiency of the system.

(*c*) Alternatively, if an increased availability is not required, the principle of pairing can be used to increase the capacity of the group selectors which, in some cases, may result in the complete elimination of a group selection stage.

The Differentiating Signal. The use of the pairing principle necessitates the provision of a differentiating signal between selectors in order to indicate the desired half of the paired group. Fig. 588 shows the basic signalling element. If an even-numbered digit is dialled, an arc of the digit switch is arranged to apply a temporary earth to the positive wire when a selector of the next stage is seized. When switching takes place, the calling loop is extended, and the selector is seized by the operation of relay *A*. The presence of the earth on the positive wire prevents the operation of relay *P*. If, on the other hand, an odd-numbered digit has been dialled, the absence of earth on the positive line at the moment of seizure allows relays *A* and *P* to operate in series, *P* locking via a local circuit. Thus, differentiation between selection by an odd or even digit is effected by the operation or non-operation respectively of relay *P*. In order to avoid circuit complications, this principle of associating odd and even digits on a paired group is followed throughout the exchange.

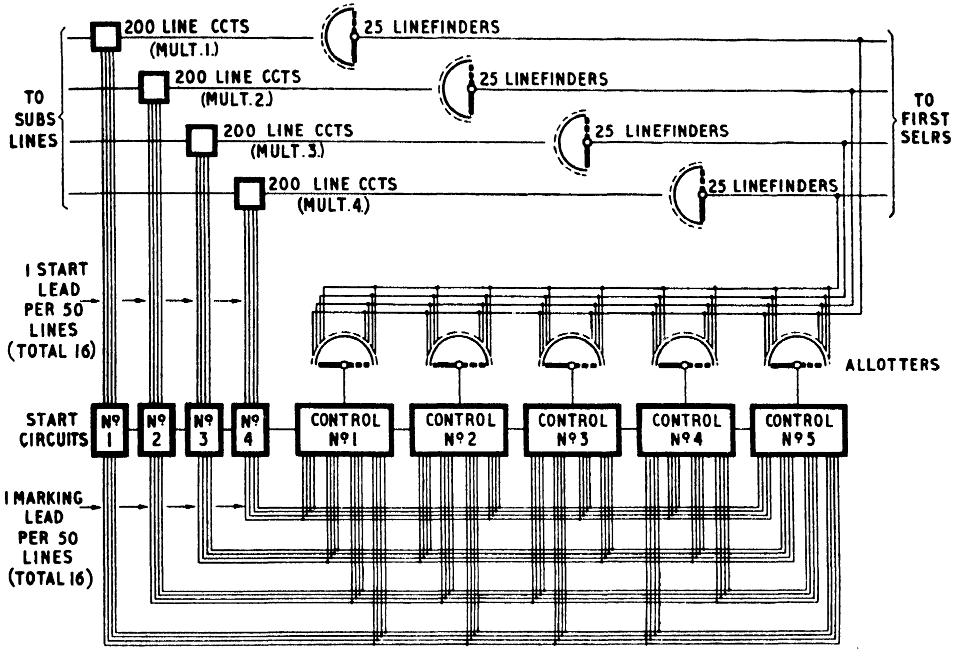


FIG. 589. TRUNKING ARRANGEMENTS OF SIEMENS NO. 17 LINEFINDER SCHEME

The Linefinder. The No. 17 System utilizes 200-point linefinders which are positioned by common control circuits and are directly connected to 1st selectors. The basic arrangement of the line, start, control and allotter circuits is shown in Fig. 589. The interesting feature is the provision of 4 start leads per group of 200 subscribers' lines and 4 marking wires (one per 50 lines) between each start circuit and all the control circuits. The banks of the linefinder switches are arranged as 4 sections, each serving 50 lines. Pairs of wipers are connected in parallel to give the equivalent of two sets, each having access to 100 lines.

When a calling subscriber lifts his receiver, the operation of the associated line relay passes a signal to the start circuit over the appropriate start lead. (The number of lines connected to one start common depends upon the traffic require-

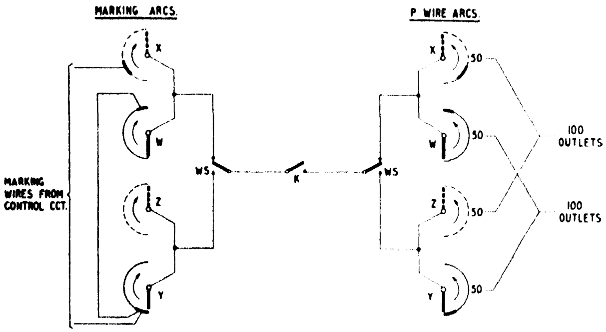


FIG. 590. GROUP SELECTING ARRANGEMENTS OF LOCAL 1ST AND INTERMEDIATE GROUP SELECTORS

ments, but is usually 50.) The calling signal is passed from the start circuit to a control and its associated allotter. The allotter (which is a motor uniselector) has access to 100 linefinders. The number of linefinder groups accessible from one allotter switch depends, of course, upon the calling rate. In practice, one allotter multiple can serve from 2 to 5 linefinder groups. The total groups served by one allotter multiple is known as a

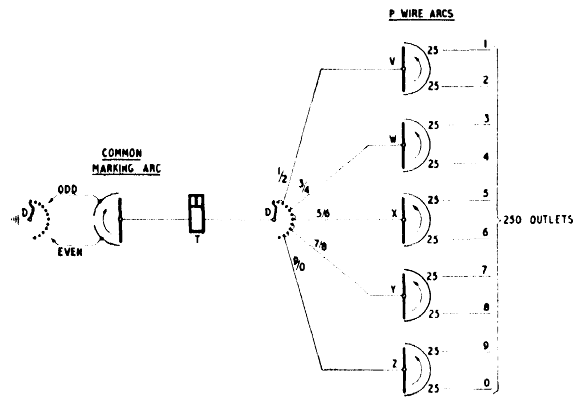


FIG. 591. GROUP SELECTING ARRANGEMENTS OF INCOMING SELECTORS

division and can give access to as many as 5 × 200 = 1000 lines. Control sets and allotters are usually provided at the rate of 5 per division, irrespective of its size.

The energization of the start circuit causes all free control circuits to hunt for the calling start circuit by means of a chain of high-speed hunting relays. One of the control circuits finds the start circuit, and its associated allotter is marked so that it will select only a linefinder which gives access to the multiple in which the calling line is situated. The conditions passed over the marking leads are extended through the control set and the allotter to indicate to the linefinder the particular group of lines over which search is required.

Unlike most linefinder schemes, the control and allotter circuits are not individual to a particular linefinder group, but are in a common pool to serve a number of such groups. This scheme avoids the difficulties which sometimes occur when there is a sudden peak of calling signals in one particular linefinder group.

Incoming and 1st Selectors. The 1st selector consists of a motor uniselector and 3 relays. The

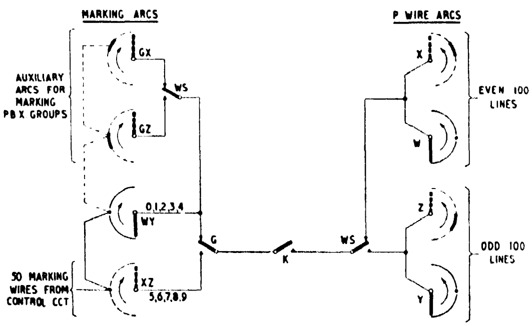


FIG. 592. FINAL SELECTOR OUTLET AND P.B.X. GROUP SELECTING ARRANGEMENTS

common control circuits are provided on the basis of one control set per six 1st selectors, each control consisting of two digit switches and up to eleven relays. Fig. 590 shows the group selecting arrangements. Access to the *X* and *Z* sections of the bank is obtained by pre-positioning the wipers (i.e. by arranging for a 180° rotation of the switch) by means of a signal from the digit switch after the dialling of the first digit. At the same time the wiper switching relay (*WS*) is operated as required, depending upon the selecting digit dialled. It will be noted that a separate marking arc is provided for each bank section, to permit of a variation in the number and size of the outlet groups in each section. Provision is made for wiper switching (operation or release of *WS*) when the wipers have completed a 90° search, thereby permitting the outlets of one group to be spread over arcs *W* or *X*, and *Y* or *Z*.

The group selecting arrangements of a 250-outlet incoming selector are illustrated in Fig. 591. In this case each arc of 50 outlets is selected by a pair of digits, i.e. arc *V* is selected by the digits

1 and 2, arc *W* by digits 3 and 4, and so on. A further subdivision is obtained by restricting access to a particular group of outlets in each arc by means of the common marking arc. It will be noted that the marking arc is common to all sections, and it follows that all sections must be alike with respect to the availability of groups. All incoming selectors are individually controlled to prevent the artificial busying of the junction routes whilst the control is engaged in the setting up of a call.

Intermediate Group Selectors. The intermediate group selectors are arranged in common control groups, each control serving 9 selectors. The group selecting arrangements are similar to those already indicated in Fig. 590. The pre-positioning of the wipers occurs on receipt of the differentiating signal, which is received from the preceding stage

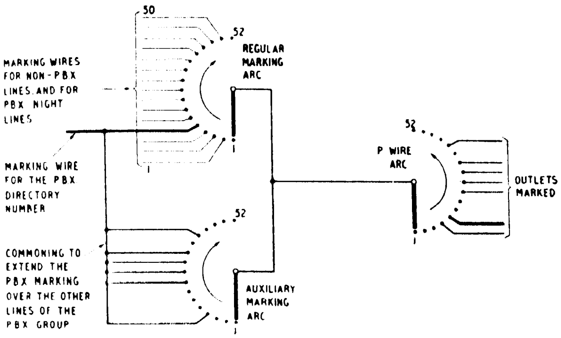


FIG. 593. MARKING PRINCIPLE FOR ORDINARY AND P.B.X. LINES

if the digit dialled is an odd number. The wiper switching relay is controlled by the digit received by the associated control relay set.

Final Selectors. Each final selector consists of a motor uniselector and 4 relays, and is controlled from a common relay set of some 12 relays (one relay set per 6 final selectors). The selector is of the universal type, i.e. it serves both ordinary and P.B.X. groups of any size. The switch bank is arranged so that pairs of adjacent sections each serve 100 lines (Fig. 592). The pairing signal transmitted from the preceding control determines in which hundred the selection is to be made, i.e. determines whether or not *WS* is operated. The particular arc (of 50 outlets) is determined by the tens digit, and the actual marking of the required line is effected over one of 50 marking wires.

P.B.X. groups are marked by extending the individual marking wires to the outlets of auxiliary marking arcs where they are commoned to the remaining lines of the P.B.X. group (Fig. 593). The P.B.X. directory number must be in the *W/Y* section of the bank, and the other lines of the group are made to appear in the *X/Z* section of the bank. Each P.B.X. group may consist of from 2 to 51 lines.

Facilities are provided in the final selector circuit for trunk offering and for the connexion of

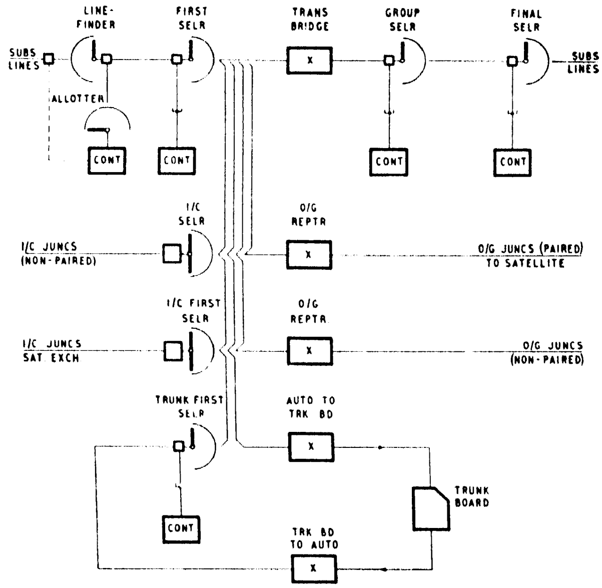


FIG. 594. TYPICAL TRUNKING ARRANGEMENTS OF MAIN EXCHANGE

the call if the subscriber agrees to accept it. Facilities are also provided for indicating to a trunk telephonist that any line is already engaged on a

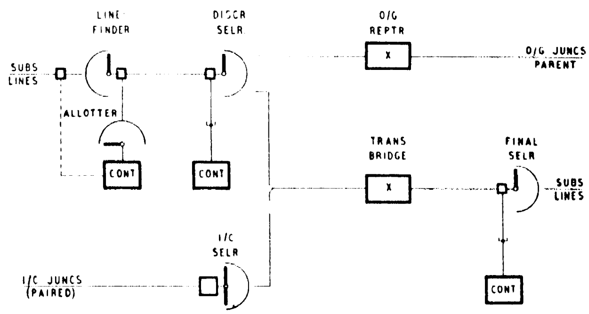


FIG. 595. TYPICAL TRUNKING ARRANGEMENTS OF SATELLITE EXCHANGE

trunk call. The ringing is not applied from the final selector, and the control set is engaged only for the period necessary to accept the tens and units digits and for the selector to make the necessary selection.

Typical Trunking. Fig. 594 shows a typical trunking diagram of a 5-digit main exchange. In

this particular example, a 10 000-line exchange is envisaged. A somewhat greater multiple could be made available by providing two divisions of group selectors, i.e. by providing more than 5 main routes from the 1st selector banks. Still larger exchanges can, of course, be designed by the addition of further group selector stages. It will be noted that the transmission bridge is placed in a separate relay set located immediately after the 1st group selector. This relay set is a jacked-in unit which accommodates, in addition to the transmission bridge element, all the necessary relays for the application of ringing current, ringing tone, and the control of metering. It is possible to locate the transmission bridge at other points, but the position shown is usually the most economical. The circuit arrangements are such that the transmission bridge is by-passed until the connexion has been made to the called line. Only at this stage is the transmission bridge switched into circuit. The arrangement materially simplifies the impulsing and signalling conditions during the setting up of a call. The switching arrangements

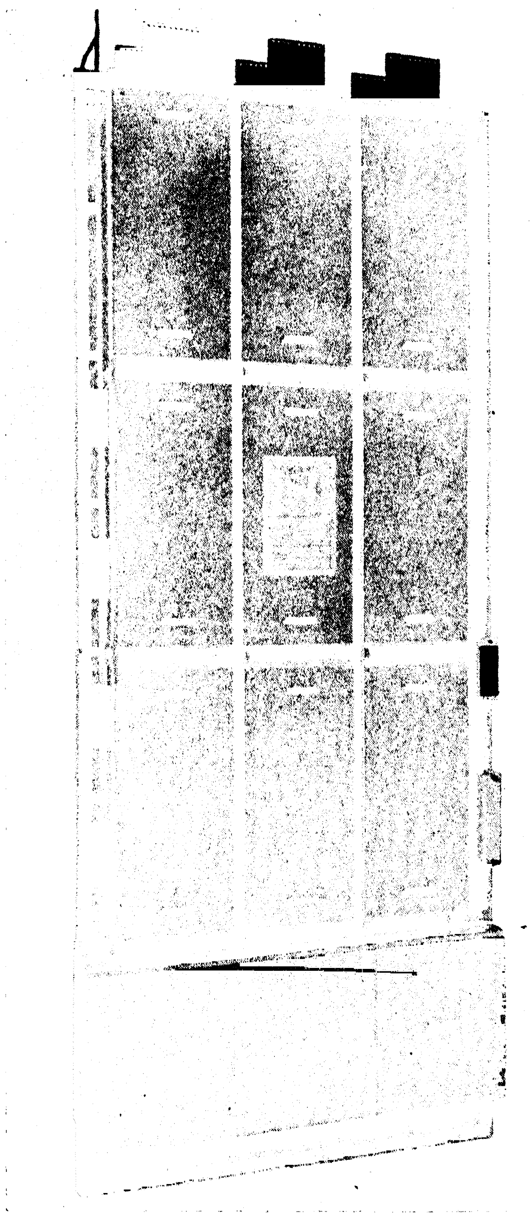


Fig. 596. Front View of Typical Selector Rack

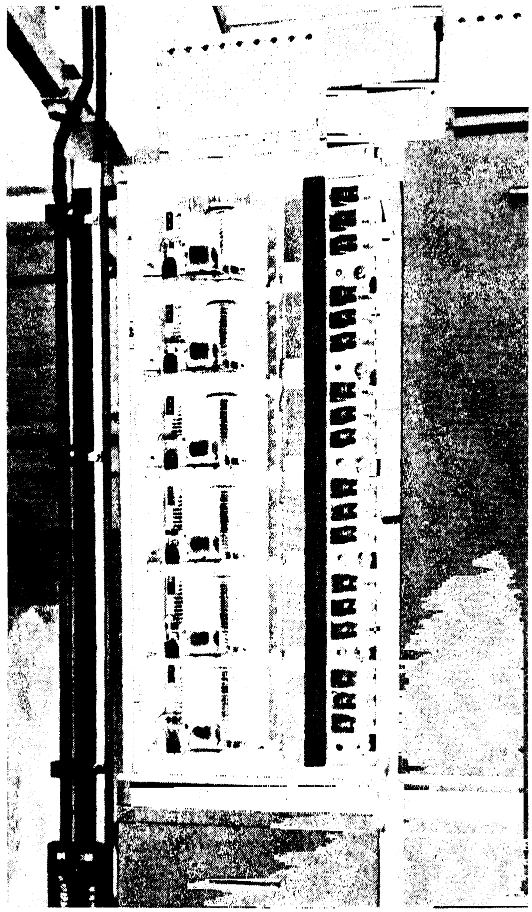


Fig. 597. Selector Panel with Cover Removed

make it possible to cut out the local transmission bridge on trunk calls.

Satellite Working. The Siemens No. 17 System makes provision for discriminating satellite working in multi-exchange areas. Fig. 595 shows typical trunking arrangements. The linefinders are directly coupled to discriminating selectors of the motor uniselector type. A group of the early choice outlets of this switch serve as a junction finder to obtain access to the main exchange junctions. The associated control circuit records the impulse trains until discrimination is complete. (Up to this stage the discriminating selector is engaging a junction to the main exchange.) If it is now determined that the call is local, the discriminating selector moves to a position further round its bank which gives access to local group or final selectors. The circuit provides for discrimination at the first, second or third digit and, when local discrimination takes place, the parent exchange junction is released in the normal manner. The three digit switches in the discriminating selector control circuit provide a high degree of flexibility in the discriminating arrangements.

Equipment Details. The rack frameworks of the No. 17 System are somewhat similar to the standard racks of the British Post Office standard exchanges. The linefinders, group selectors, and final selectors are mounted in vertical panels, each panel accommodating a group of 6 selectors (Figs. 596 and 597). The controls are placed at the bottom of the rack, and all the equipment is enclosed by covers both at the front and at the rear of the rack. Incoming selectors (which require an individual control set per circuit) are arranged in the form of 6-panel racks, each rack accommodating 36 selectors. (The 9-panel racks accommodate 54 selectors and the associated controls.) The line relay racks are double-sided, each side providing accommodation for 300 line circuits.

Grading and grouping are carried out between the 6-selector units, and the outgoing and incoming trunks from each rack are terminated on connexion strips at the top of the rack. The arrangements are such that (by the use of temporary supports) the whole of the cabling external to the racks can be completed before the racks themselves are delivered. This enables most of the rough installation work to be completed and the switchroom cleaned up before the apparatus is brought on site.

Apart from the main features described in the preceding paragraphs, the No. 17 System provides a number of facilities to assist in the tracing of calls, the treatment of C.S.H. conditions, and so on.

EXERCISES XIX

1. Explain, with the aid of suitable diagrams, the principle of "marker control" as applied to mechanisms of the unidirectional type.

2. The traffic at the 1st selector stage of an automatic exchange is divided into five groups as follows:

Digit 1— 1 T.U. to N.U. Tone equipment.
Digit 2—50 T.U. to 2nd selectors (level 2).
Digit 3—40 T.U. to 2nd selectors (level 3).
Digit 4—30 T.U. to adjacent exchange.
Digit 0— 3 T.U. to automanual board.

Suggest a possible trunking scheme when the 1st selector is:

(*a*) of the 2-motion type with an availability of 20 per level, and

(*b*) of the uniselector type with a total bank capacity of 200 outlets.

Illustrate with suitable diagrams and show on the diagrams the number of trunks required to give the standard grade of service in each case.

3. One of the main problems in the design of a uniselector switching scheme is to ensure that the selectors can reach any required contact within the time available between successive digits. Describe the various methods which have been adopted in practical uniselector systems to meet this requirement.

4. Some uniselector switching systems provide for combining the traffic of two or more routes between selector stages. What is the purpose of such a practice, and what factors must be taken into consideration in determining the economics of the arrangement?

5. Discuss the advantages and limitations of "motor drive" and "ratchet and pawl drive" for automatic selector mechanisms. How does the method of control influence the type of drive?

6. Give a schedule of the main differences between the French R6 System and the Bypath switching system. What exactly are the reasons for the provision of "bypaths" in the latter?

7. Describe, with the aid of suitable circuit elements how, in the French R6 System:

(*a*) a selector is engaged when the associated control is in use by another circuit, and

(*b*) a free outlet in the required group of trunks is tested and the call switched to this outlet. What happens when two selectors test the same outlet concurrently?

8. Describe the main trunking principles of the S.17 System. What method of signalling is employed between selector stages on "paired" groups?

9. Give a trunking diagram of the linefinder scheme of the S.17 System. Compare the merits and limitations of this scheme in relation to a 200-point linefinder system with partial secondary working and utilizing 2-motion Strowger selectors.

10. Give a diagram and describe the principle of operation of a circuit suitable for directing a motor uniselector to a free contact in a preselected group of trunks. Explain concisely how testing and switching are effected.

CHAPTER XX

POWER DRIVE SYSTEMS

THE automatic switching systems so far described in this volume have been based upon mechanisms provided with a drive system individual to the selector. There is a number of other successful and widely used systems where the selecting mechanisms are positioned by coupling the selector to a suitable arrangement of power-driven shafting. In some of these systems power is derived from an electric motor common to all selectors on the same rack or bay. In other cases a single motor may serve a whole suite of racks. The drive may either be continuous or may be arranged on a start-stop basis, as required.

Possibly one of the greatest merits of a power drive system is the large driving torque available for moving the selector mechanisms. This in turn makes it possible to design switches which are very robust in construction and of a large bank capacity. On the other hand, the use of a drive source which is common to a large number of selectors makes the system somewhat more liable to a major breakdown in the event of a failure in the power drive arrangements.

The use of large capacity selectors prohibits the use of a simple method of decimal selection (as in the Strowger scheme), and hence most practical power drive systems are based upon the principle of non-decimal selection. In some systems the selectors are positioned by control circuits individual to each stage. Under these conditions it is possible to employ either a marker system of control (as described in Chapter XIX) or some method of revertive impulse control. (The principle of revertive impulse control has been outlined in Chapter I—see Fig. 10.) In other systems the successive selectors of the switching train are all positioned under the control of a common register or similar circuit. With such a centralized method of control, it is not readily possible to utilize the marker control principle, and such systems are usually designed on the basis of revertive impulse control.

It is not possible in the space available in this volume to describe all the various forms of power drive system, but a brief outline is given in the paragraphs of this chapter of three typical and widely used systems.

ERICSSON 500-LINE SYSTEM

The Ericsson 500-line system, which has been installed at Stockholm and in many other cities, is interesting in that it employs a selector, the wipers of which move consecutively in two directions in the same plane (Fig. 598).

The bank contacts are formed by long vertical lengths of bare wire attached to a base of insulating material. The contact wires of 20 outlets are assembled together as a vertical *section* of the bank, and up to 25 such sections are arranged in a radial formation so that the whole bank subtends an angle of 90°. The rack on which the bank is

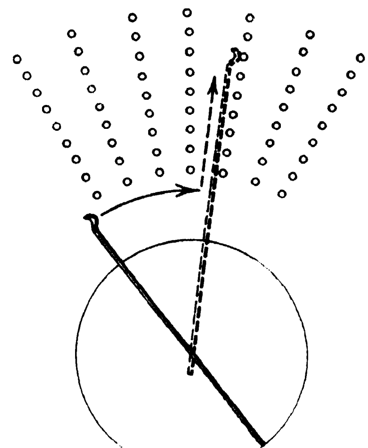


FIG. 598. MOVEMENTS OF ERICSSON 500-LINE SELECTOR

mounted can accommodate from 40 to 70 switches depending upon the height available. On the top of the frame the bank wires are terminated on switchboard cables, and are then led to the various distribution frames.

The mechanisms are power-driven from a system of shafting installed throughout the exchange, which is driven from a common source. Each switch has access to a total of 25 × 20 = 500 outlets, and the arrangements are such that translators are necessary to convert from the decimal system of signalling from the subscriber's dial.

Fig. 599 shows a typical selector and part of the bank assembly. The selector mechanism is readily jacked out from the frame, the connexions being made by the jack seen on the left.

Selector Mechanism. Fig. 600 shows the mechanical arrangements in greater detail. *S* indicates the continuously rotating shaft which extends the

full length of the selector rack. The clutch magnet is mounted directly on the base-plate (*BP*) and has two windings *MH* and *MV*. The spindle (*M*), carrying the toothed wheels *FR* and *FR'*, passes through the armature which is common to both coils. There are two drive wheels associated with each mechanism (shown on the right of Fig. 599), i.e. the armature can be attracted either by the coil *MH*, so connecting *FR* to the upper gear wheel, or by coil *MV* in order to connect *FR* to the lower gear wheel on the vertical shaft common to the rack. By this means two opposite rotary movements can be communicated to the spindle.

The rim of *KR* conveys the movement from shaft *M* to the rotary disc and to the contact arm. The teeth on its outer edge mesh with *FR'*, whilst those on the inner edge mesh with the toothed wheel *ZR*. *ZR* is pivoted on the rotary disc *TS* and transmits the movement from the rim gear wheel to the contact arm *KA*.

The rear part of the contact arm is in the form of a rack which meshes with wheel *ZR*. (Actually *ZR* consists of two wheels pivoted on the same shaft, the lower one being geared to the rim *KR* and the upper one to the rack on the contact arm.) The contact arm *KA* is mounted on the rotary disc *TS*, and at one end supports the three selector contact springs *a*, *b*, and *c*. The portion of the contact arm which moves into the multiple is covered with an insulating sleeve to prevent irregular contact with the bank.

The contact arm first rotates with the disc until it is positioned against the particular multiple frame required, and then moves out radially into the bank of that frame. These movements are controlled by means of the two locking or centring magnets *CV* and *CR*. *CV* is the locking magnet for the rotary movement of the selector, its armature forming a detent (*EV*) which fits into notches on the rotary disc. The notches are spaced to conform to the position of the contact arm in relation to the multiple frames, and when *EV* is released the rotary disc is securely locked in position. There are 26 rotary positions of the disc, i.e. 1 home position plus the 25 positions of the radial bank units.

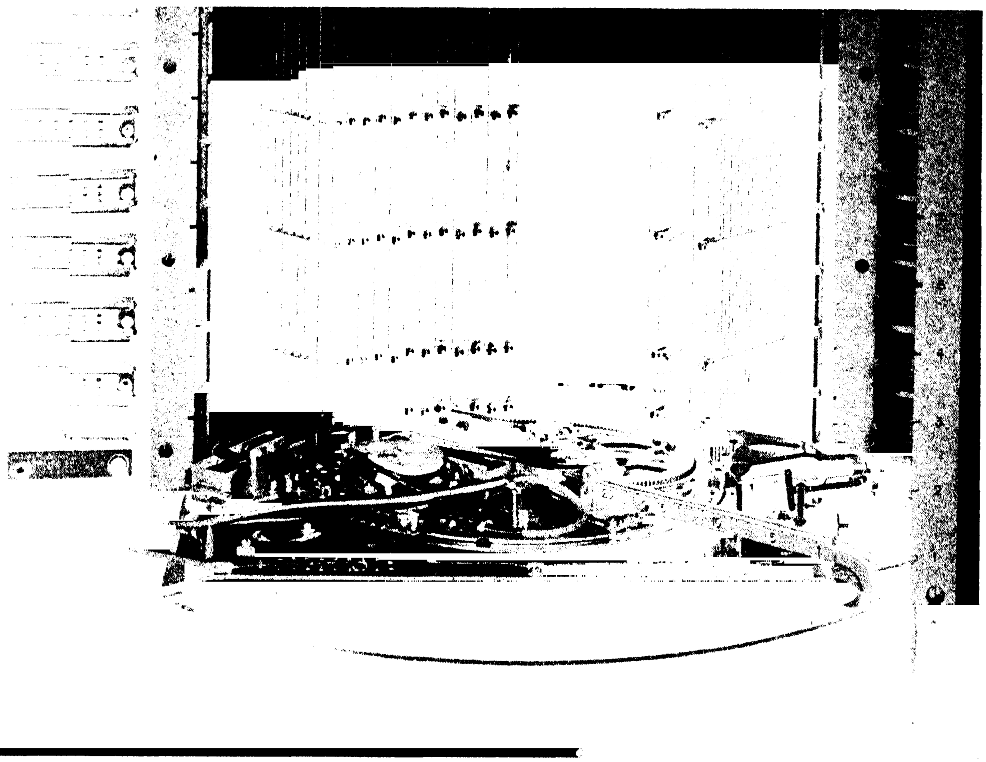


Fig. 599. 500-line Selector and Bank

The rear end of the base-plate is formed into a protective bow which is engraved to show the rotary position of the contact arm. Similarly the arm itself is graduated 1 to 20 to enable the

particular line in the frame to be ascertained (see Fig. 599).

The magnet (*CR*) is the locking magnet for the radial movement. Its armature is formed into a detent (*ER*) which centres and locks the contact arm at the termination of radial movement.

The clutch electromagnets *MH* and *MV* are connected through contacts on the locking magnet armatures (*EV* and *ER*). When *CV* is energized, the selector is released for rotation, and the rotary disc can move to the right or left depending upon which of the two coupling coils *MH* or *MV* has been operated. This movement continues until the circuit through *CV* is broken and the detent engages a notch in the rotary disc. The rotary disc is now locked and the current supplied to *MH* or *MV* is disconnected. *CR* is now energized and in turn re-operates *MH* or *MV*. The contact arm now moves in a radial direction until the required line is found, when *CR* is released to lock the contact arm and to disengage the selector from the rotating shaft.

Fig. 601 shows a selector mechanism removed from the bank.

Apart from minor differences, all selectors are of the same general design. Linefinders are provided with a special test spring (known as the *D* spring) which is mounted on the rotary disc in such a position that it makes contact with the front vertical bars of the multiple frames in the linefinder banks. These bars are used as test bars to determine the particular frame in which the calling line is situated. Linefinders are not provided with a home position for rotary movement.

Group and final selectors, on the other hand, have a definite home position for both radial and rotary movements. Both selectors are provided with a common plate mounted on the rotary disc which alternately closes and opens a pair of contact springs during the rotary movement. The current pulses from this spring set are reverted to the register to control the movement of the radial arm. Group selectors are arranged to give automatic radial hunting, and hence no control from the register is required for this movement. Final selectors, on the other hand, have to be directed to a particular set of contacts, and an additional revertive impulse cam is fitted on such selectors to provide control of the radial movement.

All selectors are provided with two extreme switching positions so that the rotary and radial drives are reversed automatically should the mechanism be driven to the end of its movement.

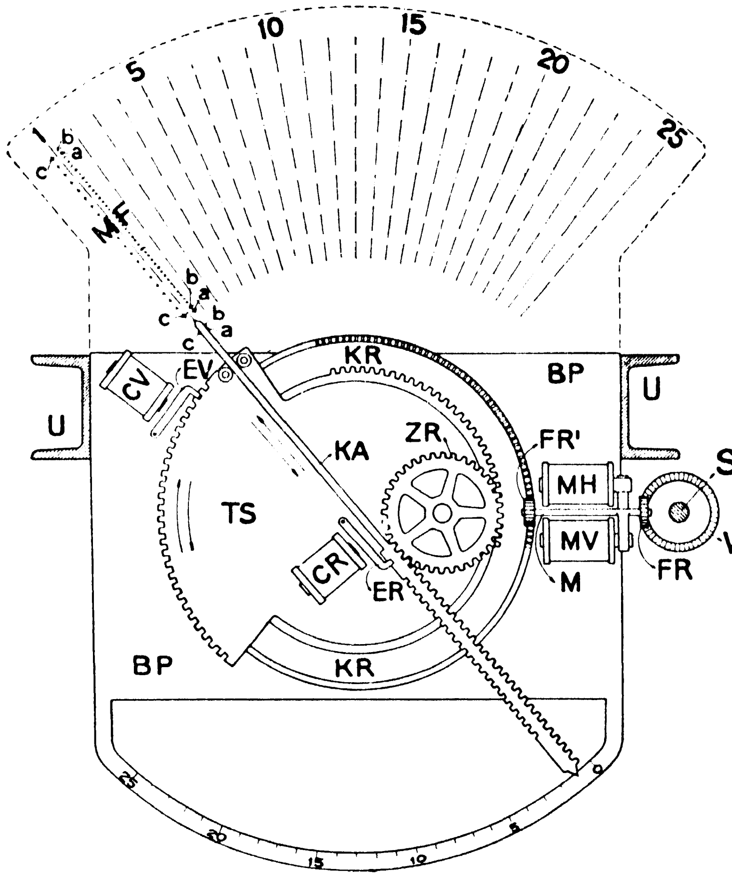


FIG. 600. MECHANICAL ARRANGEMENTS OF SELECTOR MECHANISM

The selector is connected by means of a flexible cord and an 18-point plug to the rack circuit.

Trunking Arrangements. Fig. 602 shows typical trunking arrangements at a 10 000-line exchange. The subscribers' lines are arranged in groups of 500, each group being served by a number of linefinders. The number of linefinders required for any particular group depends, of course, upon the calling rate but, in practice, it usually varies between 25 and 50. Each linefinder is directly connected to a group selector which, in turn, can be used to give up to a maximum of 500 outgoing

trunks. Usually only 20 of the 25 available bank frames are utilized for trunks to the final selector groups, the remaining frames (Nos. 21 to 25) being reserved for special services. In these circumstances each group selector has access to 20 different groups of final selectors with an availability of 20 on each group. The subscribers' lines are arranged in groups of 20 on each frame of a final selector multiple, 25 such groups being served by one group of final selectors. The introduction of a second group selector stage increases the theoretical capacity of the trunking scheme to 250 000 lines.

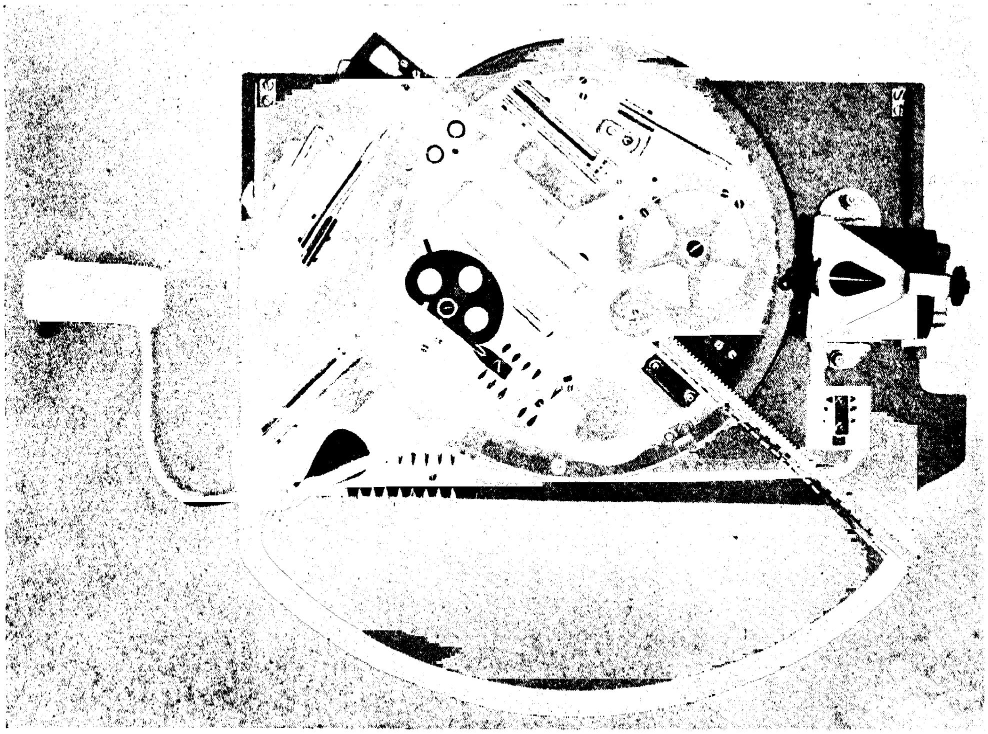


FIG. 601. PLAN VIEW OF ERICSSON SELECTOR

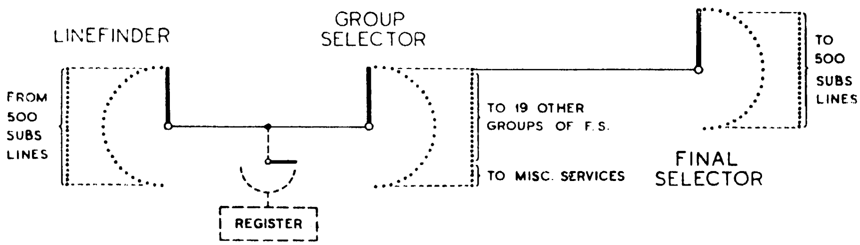


FIG. 602. SIMPLIFIED TRUNKING SCHEME OF 10 000-LINE EXCHANGE

When a calling party lifts his receiver, a line-finder in the appropriate group searches for and seizes the calling line and extends it to a register. The register itself contains a number of power-driven uniselector type mechanisms on which the digits dialled by the subscriber are stored. The register controls the movement of the group and final selectors by counting the impulses returned from the switches as movement proceeds. In order to minimize the number of relays, sequence switches are used in the registers to effect the circuit changes at each stage in the process of selection.

THE ROTARY SYSTEM

This System is manufactured by the International Standard Electric Corporation, and at the present time there are more than three million lines in service in some thirty different countries. The Rotary System has been adopted by the French Administration as the standard system for use in and in recent years considerable development has taken place in the provision of rotary equipment for automatic toll switching. Important toll switching centres, such as Zurich, The Hague, and Amsterdam, are provided with rotary automatic toll switching equipment.

The 7A System utilizes 100- or 200-point linefinders, 300-outlet group selectors and 200-line

FIG. 603. TYPICAL LINEFINDER AND FINAL SELECTOR RACKS—ROTARY EXCHANGE

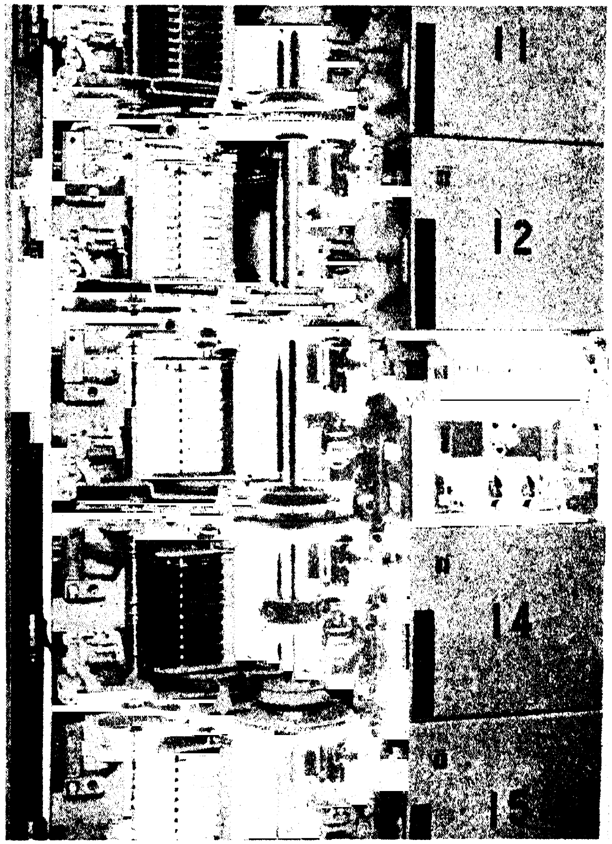


FIG. 604. DETAILS OF SHAFTING, GEARING, ETC. ON FINAL SELECTOR RACK

Paris and it has also been installed in a number of capitals and other large cities throughout the world. The system has not been used to any extent in Great Britain, but experimental rotary exchanges were installed at Darlington and Dudley some years ago.

The No. 7A System is particularly suitable for large city areas, whereas for smaller towns, single exchange areas, and rural networks, the No. 7D System is generally more economical. Several different variations of the Rotary scheme have been designed to meet particular requirements, final selectors. The 7D System, on the other hand, uses only 100-point power-driven switches both for the linefinders and for the selectors. The 7A System employs the revertive impulse method for controlling selection, whereas in the 7D System the selectors are controlled by impulses passed forward either by a register or from the calling subscriber's dial. A further distinguishing feature of the 7A System is the use of sequence switches in the selector circuits. The 7D System, on the other hand, employs relays for the control of all conversational circuits, and in certain common

control and register circuits small step-by-step switches are used in addition to relays.

Power Drive. The Rotary System derives its name from the fact that all switch mechanisms are of the unidirectional rotary type. The selectors are power-driven by means of a system of continuously rotating shafting. Fig. 603 gives a general view of a typical linefinder and final selector rack. The selectors are arranged in the rack framework with their banks in a horizontal plane, and are driven by means of a vertical shaft which extends the full height of the rack. The vertical driving shafts are coupled to a main horizontal shaft at the bottom of the rack by bevel gears, and the main shaft is in turn driven by a small motor which is coupled to the shaft via a worm reduction gear. In a 10 000-line exchange each double rack (of which there are seven) is served by a $\frac{1}{8}$ h.p. motor which may, if desired, be controlled by a motor start circuit during periods of light load.

Fig. 604 shows part of the final selector rack in greater detail, and clearly illustrates the system of gearing by means of which the selector is associated with the vertical shafting. The cover of control circuit No. 13 has been removed to show the sequence switch, which also derives its movements from the shafting. The vertical shaft is provided with a flat gear wheel (punched out of nickel silver sheet) opposite each selector. The corresponding gear wheel on the selector is flexible, and is normally held out of mesh with the driving gear by downward pressure from a powerful helical spring on the controlling electromagnet. To drive the switches, current flows through the control magnet, and the resultant attraction of the armature removes the pressure from the flexible gear of the selector. The latter now moves upwards and engages with the driving gear. When the circuit of the control magnet is opened, the release of the armature deflects the flexible gear out of mesh with the driving gear and holds it against a back stop placed on the under side of the flexible gear. In this position the armature stud acts as a positive brake on the gear, thereby preventing the kinetic energy of the moving parts from carrying the wipers beyond the desired position, and also holds them rigidly in position during the time the switches are stationary.

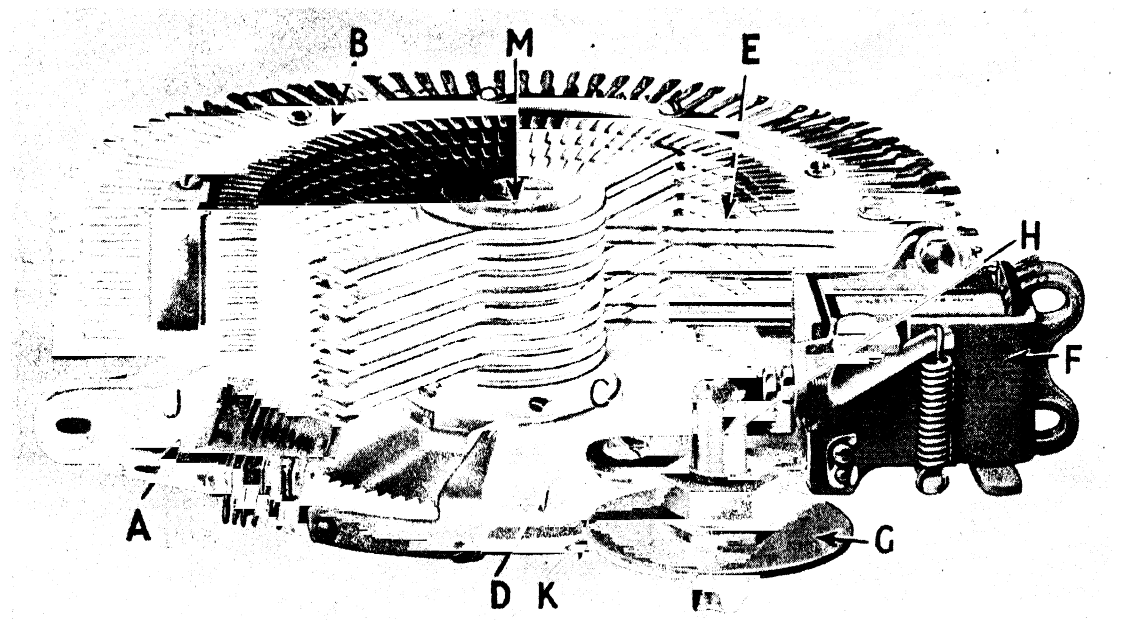


Fig. 605. 100-point Linefinder

A = Frame
B = Arc
C = Rotor
D = Flexible gear
E = Feeder brush
F = Clutch
G = Drive
H = Common bay shaft
J = Home contact (homing switches only)
K = Back stop
M = Steel pivot

Linefinder. The Rotary System utilizes 100-point or 200-point linefinders for associating the

subscribers' lines with the 1st selectors. A view of a 100-point linefinder is shown in Fig. 605. It comprises a moulded bakelite bank with a capacity of 10 or 14 rows each of 51 bank contacts arranged in an arc of 180°, a brush carriage consisting of a number of wipers (or brushes) mounted on a central spindle, and a driving mechanism with its electromagnet. Connexion to the wipers is made by feeder brushes held in a moulded bakelite block. The various components are assembled on a die-cast frame, which is provided with three lugs for fixing the mechanism to the rack framework. The wipers are stamped out of nickel silver sheet and are provided with phosphor bronze contact tips. In addition, removable fibre shoes are slipped over the ends of the wiper to guide them into the bank and to facilitate smooth rotation over the bank terminals. The controlling electromagnet is of single coil design, and is self-protecting.

The linefinder is designed to rotate at a normal speed of 45 contacts per second. In spite of this comparatively high hunting speed, there is ample margin to stop the brush carriage securely on the proper bank contacts under the most adverse conditions of motor speed, battery voltage, etc. The contact pressure for the wipers is 35 g. The 200-point linefinder is of the same general design as the 100-point linefinder, but comprises a moulded bakelite bank with 10 rows each of 101 bank contacts.

Selector Mechanism. Fig. 606 shows the principle of operation (in diagrammatic form) of the main selector mechanisms of the Rotary System. Fig. 607 gives a general view of a final selector, whilst Fig. 608 shows the component parts of a group selector. The bank consists, for a group selector, of 30 vertical rows of contacts and, for a final selector, of 20 vertical rows of contacts. Each group of three horizontal arcs of contacts constitutes a level. The brushes (or wipers) are carried on the central rotor (which is mounted above the driving wheel) and are normally held away from engagement with the bank contacts by a latch block. To the left of the mechanism is the trip spindle, which trips the latch of the set of brushes associated with the level over which the call is to be extended. This trip spindle is provided with 10 trip fingers and can be rotated to 11 different positions (one of which is its normal position). At the top of the trip spindle are the spring sets and cams which transmit the revertive impulses to the register as the trip spindle moves into position. Similarly, the commutator seen above the bank in Fig. 607 produces the revertive impulses as the brush carriage of the final selector rotates.

When the selector is taken into use, the left-hand electromagnet is energized, thereby allowing the lower toothed wheel to engage with the shaft driving wheel. The trip spindle is now rotated, and during rotation impulses are returned to the register. When the correct number of reverted impulses has been received, the drive is disconnected. The trip spindle has now been set for tripping the brushes on the required level as they pass by. The register operates the right-hand electromagnet, so bringing the upper toothed wheel into engagement with the associated driving wheel. The brush carriage now rotates, and as the brushes pass the trip spindle the required set is tripped into engagement with the bank contacts, thereby

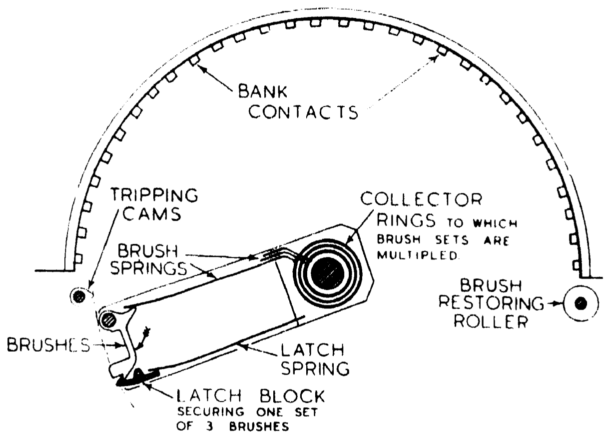


Fig. 606. Principle of Rotary Selector

providing search over the desired level. At the end of the call the rotary drive is reconnected and, as the brush carriage passes the thick re-setting roller (seen on the right of Fig. 607), the brushes which were tripped as they moved into the bank are now pressed back, and the latch slips into position to hold them away from the bank. The trip spindle is next returned to normal.

Should all the outlets in the level be engaged, the trip spindle remains set so that, although the brushes are returned to normal as they pass out of the bank, they are re-set as the brush carriage passes the trip spindle on their second entry into the bank. The selector therefore commences a second test over the same level, and this continuous rotary action is maintained until the drive is disconnected by the de-energization of the right-hand control magnet.

An interesting feature of the Rotary System is the use of woven silk ribbon cables for the interconnexion of the selector banks. It is claimed that this method of construction requires very little space for the bank multiple and greatly facilitates

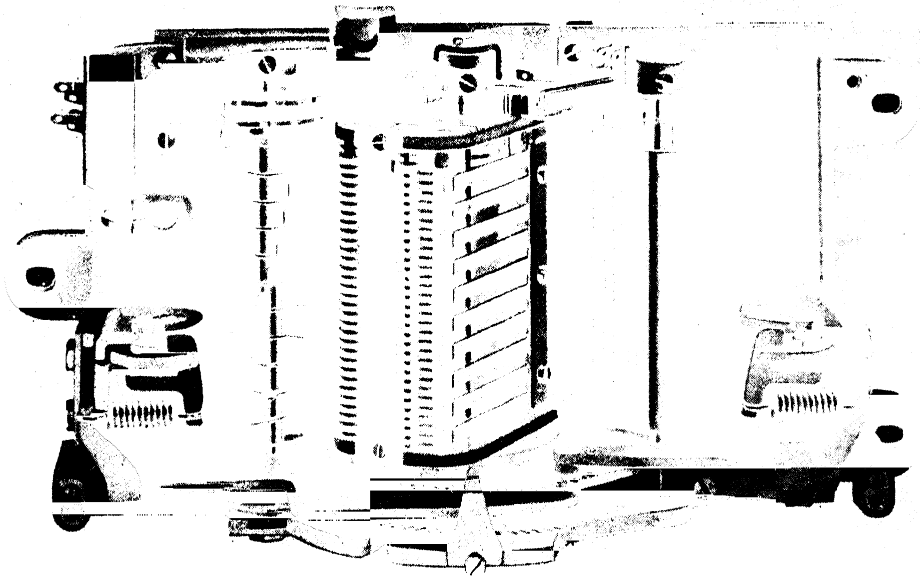


FIG. 607. THE FINAL SELECTOR

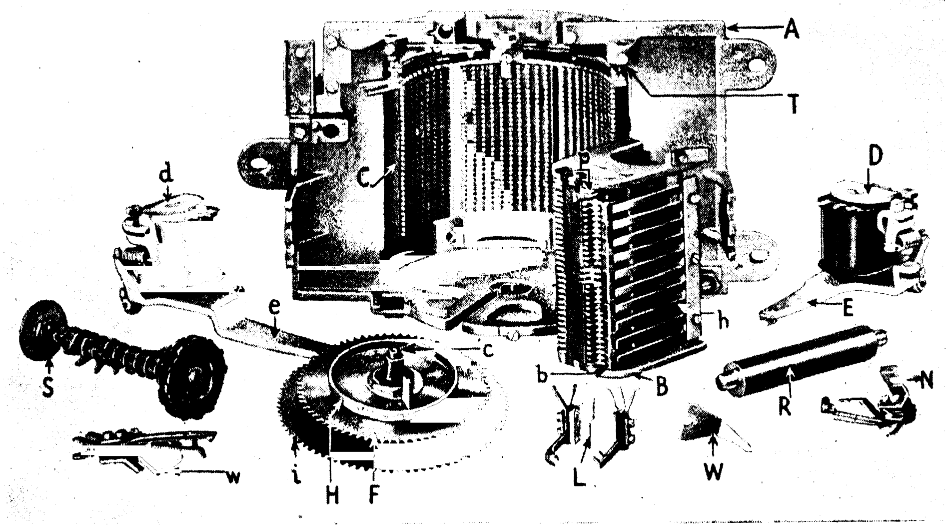


FIG. 608. COMPONENT PARTS OF GROUP SELECTOR

A = Frame
B = Brush carriage
C = Terminal block
D = Brush carriage clutch magnet
E = Brush carriage clutch armature
F = Brush carriage flexible gear
H = Position indicator wheel
L = Collector springs
N = Brush carriage home contacts
R = Restoring roller
S = Trip spindle
T = Special commutator
W = Position pointer
b = Latch blocks
c = Pivot pin
d = Trip spindle clutch magnet
e = Trip spindle clutch armature
h = Latch block spring
i = Trip spindle flexible gear
p = Earthing brushes
w = Trip spindle home contact

maintenance access Fig 609 shows a rear view of a selector rack with two of the dust covers removed to show the ribbon multiple cabling and the method of obtaining access to the wiring of the relays and sequence switches

Sequence Switch. The sequence switch, a typical example of which is shown in Fig 610, is a form of power-driven relay and is used in all the more important circuits of the 7A System The centre spindle, which may be stopped in any one of 18 rotary positions, carries from 8 to 28 cams depending upon the circuit requirements Each cam consists of a phenol-fibre disc placed between two phosphor-bronze discs, the three pieces being riveted together The phosphor-bronze discs are in contact with each other but are insulated from the central spindle The discs are cut in such a manner as to eliminate metallic contact in those positions in which the circuits controlled by the sequence switch are required to be disconnected Flexible phosphor-bronze springs make contact with the discs and are arranged in groups of four, i e two on each side of a disc The appropriate cutting of the disc permits circuits to be closed or opened between the four brushes in any desired combination by rotating the central spindle to the required position

The spindle is driven from the common vertical shafting in such a manner that it makes one complete revolution during every call Each position of the switch is usually devoted to some particular circuit condition The spindle also carries a translucent position indicator illuminated by a small lamp so that the position of the switch can be readily observed through a small glass panel

Trunking Arrangements of 7A Rotary System. A simplified trunking diagram for a 10 000-line exchange of the 7A2 type is given in Fig. 611 First linefinders (and sometimes secondary line-

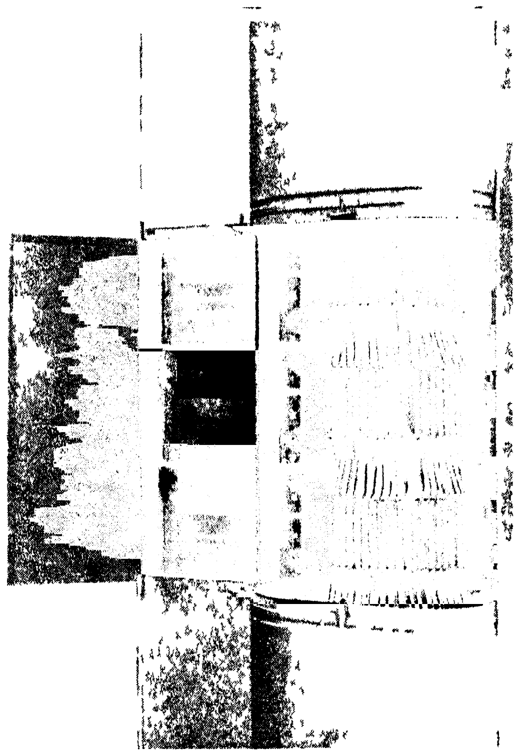


Fig 609 Rear View of Rotary Selector Frame with Dust Covers Removed
(Note ribbon multiple cable)

finders) are employed to connect a calling line to a 1st group selector The line is then extended via

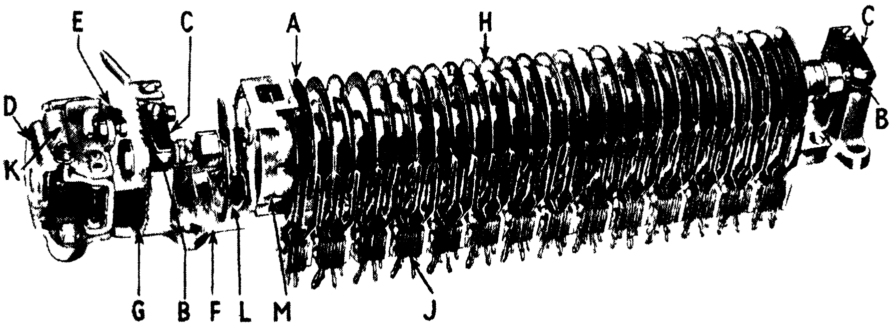


Fig 610 Sequence Switch

A = 'A' cam
B = Self aligning bearings
C = Bearing clamps
D = Clutch
E = Armature adjusting stud
F = Switch frame
G = Flexible gear
H = Regular cams
J = Spring nests
K = Armature spring
L = Indicator lamp
M = Translucent position indicator

a register link to a register. The impulses from the calling subscriber's dial are received by the register, which then proceeds to direct the movement of the selector wipers. The impulses as transmitted from the subscriber's dial are of the loop-disconnect type with a break ratio of 2 : 1, as in the Post Office standard system. The impulse frequency is also the same as in the British Isles, i.e. 10 I.P.S.

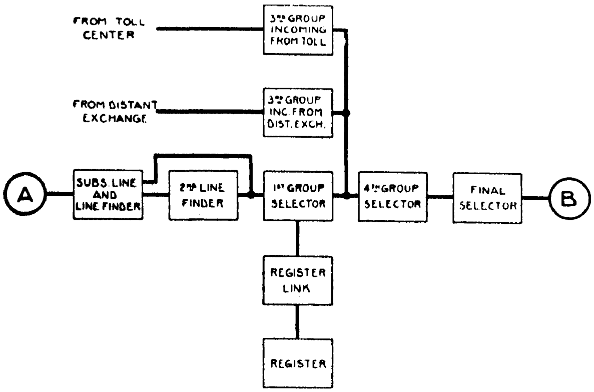


FIG. 611. BASIC TRUNKING SCHEME OF 7A ROTARY SYSTEM

In an exchange with an average calling rate, a group of 200 subscribers' lines may be served by 20 linefinders, of which 15 are wired straight to the 1st group selector, and 5 are connected via secondary finders to the 1st group selectors. When a call originates, all the free directly-connected linefinders search for the calling line. The start circuit is arranged so that the 5 indirectly-connected linefinders are not brought into use until all but one of the directly-connected finders are engaged. In this case the secondary finders now search for one of the indirectly-connected linefinders and, when one is seized, it hunts for the calling line.

As indicated in the trunking diagram, secondary finders may be omitted if the traffic does not warrant their inclusion. In some circumstances it may be desirable to complete all calls over first and secondary linefinders, and in these cases it is usual to utilize the 100-point finder in both the primary and secondary stages. When the first linefinder switches to the calling line, the subscriber is extended by means of the register link to a free register. The register link comprises two finders, one having access to 100 1st group selectors, and the other to 100 registers. Dialling tone is now returned to the calling subscriber from the register.

The Register. The register contains a group of 12 relays for counting the incoming impulses from the subscriber. During the pause after the first digit, a marking condition is transmitted from the counting circuit to a group of 4 storage relays, and the counting relay circuit is then restored in readiness for receiving the second digit from the subscriber, and so on. The different stages during the reception of the incoming digits are controlled by a sequence switch.

A second set of relays is provided in the register for counting the impulses reverted from the selector during the setting up of the call. These relays are also controlled by a sequence switch, and provision is made for up to 7 stages of selection. A jumpering field is provided between the digit storage relays and the revertive impulse counting relays. By suitable jumpering either 4-, 5-, or 6-digit calls (or a numbering scheme comprising a mixed number of digits) can be catered for. The routing of the call can be made quite independent of the impulses dialled by the subscriber, the routing in any particular case being readily modified to suit changing traffic conditions. When required, a translator switch can be introduced between the storage relays and the revertive impulse counting relays, but the flexibility of the register jumpering field makes the translator unnecessary except in very large networks.

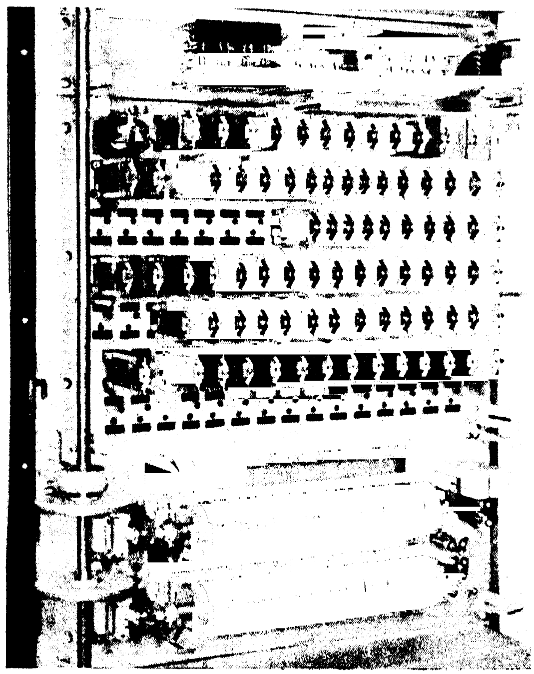


FIG. 612. EQUIPMENT OF REGISTER CIRCUIT

An interesting feature of the Rotary System is that, in the event of selectors not finding a free

outlet at any particular stage, the register will wait until one becomes free. A further feature is that, should all 30 trunks in one of the 10 levels selected be found busy, the system permits the selector, first to search the chosen level, and subsequently to search, during the second rotation, the 30 outlets of the succeeding level, thereby extending the availability to 60 outlets.

Fig. 612 shows the equipment of a typical register. It consists of a number of rows of relays, and two sequence switches. The first sequence switch controls the receipt of the impulses dialled by the subscriber, whilst the second switch controls the process of setting up the required connexion. It will be noted that the relays are of the flat type described in Vol. I.

The 7D System. The No. 7D Rotary System was primarily designed for rural networks, but it can also be used in large exchanges in a multi-exchange area. The first large area served by the system was the Zurich rural area which was automatized in 1932, and now comprises some 55 exchanges with a total of nearly 30 000 lines. The system has now been installed in about 20 different countries where there are more than 750 exchanges catering for nearly half a million subscribers.

Fig. 613 shows a simplified trunking diagram of a 10 000-line "main" exchange (A) with a 1000-line "centre" exchange (B) on which is dependent a small 100-line "end" exchange (C). These correspond roughly to the group centre, minor exchange and dependent exchange respectively of the British system. All the exchanges are of the 7D type. The main and centre exchanges employ similar trunking schemes, but the small end exchanges are of a simplified type in which the registers and the time and zone metering equipment are omitted. The simplified trunking arrangements are generally economical up to 300 or 400 lines, but the scheme permits of individual exchanges up to 1000 lines if required.

In the large type of exchange, local calls are established via 1st and 2nd linefinders, group selectors and final selectors. In the small exchanges (e.g. C of Fig. 613) a combined linefinder and final selector is used. When a subscriber lifts his receiver to originate a call, the linefinder extends the caller to the "parent" centre exchange where the call is routed to a register. If the digits dialled are those for a local call at the end exchange, the combined linefinder and final selector, together with the junction and all the equipment at the distant exchange, are released, a local link circuit being provided for the call. The discrimination is determined by a control circuit (CC) at the local exchange. This circuit is temporarily engaged for all calls and verifies whether the call is local or distant. In the case of a local call, the control circuit engages a local link (which comprises a linefinder and a final selector) over which the local connexion is established.

All outgoing junction calls from the end exchange are established via the junctions to the centre exchange. On such calls the control circuit in the local exchange and a register at the distant exchange are engaged, and the digits dialled by the subscriber are repeated to both circuits. The control circuit in the end exchange is disconnected immediately the call has been verified as outgoing, and the connexion is then completed under the control of the register at the centre exchange. Time and zone metering equipment (M) is provided at the centre exchange, and the circuit is set to the appropriate fee by signals from the register. Metering commences when the call is answered, but the detailed method of applying the metering signal varies with the requirements of different telephone administrations. The most general scheme is to provide one metering impulse immediately after the call is answered, and a further series of impulses some 5 or 10 sec later to make up the total charge for the first 3 min of conversation. (This method permits the subscriber to release the connexion before the full fee is registered in cases where a wrong number is obtained.) The metering impulses are repeated at the beginning of every 3-min period, and the connexion is automatically broken down after 12 min of conversation —a warning tone being given 10 sec before the disconnexion.

The selectors of the 7D system are positioned by a common control circuit which serves 10 selectors. When a selector is taken into use, the control circuit is temporarily connected to the selector until such time as a free outlet is found in the group marked by the control circuit. When no free outlet is immediately available, the selector hunts continuously for a period of 30 sec, when the drive is cut by both the register and the control circuit.

The division of the 100 outlets of the group selector bank can be arranged as required by the number of groups and the volume of traffic in each group. The arrangements are such that the levels and outlets can be allocated in accordance with the traffic requirements, so that in every case the full bank capacity is utilized. This feature is particularly important when the number of groups is small as, for example, on a 1st group selector where there are only a few groups of 2nd selectors.

The system is designed for operation by loop-disconnect impulses from the register. D.c

impulsing is used on junctions up to 1600 Ω loop resistance, but on the longer routes 50 cycle or voice-frequency signalling is used. In such cases power-driven register-controlled switching scheme using, for all stages, single-motion 100-point selectors of the type illustrated in Fig. 605.

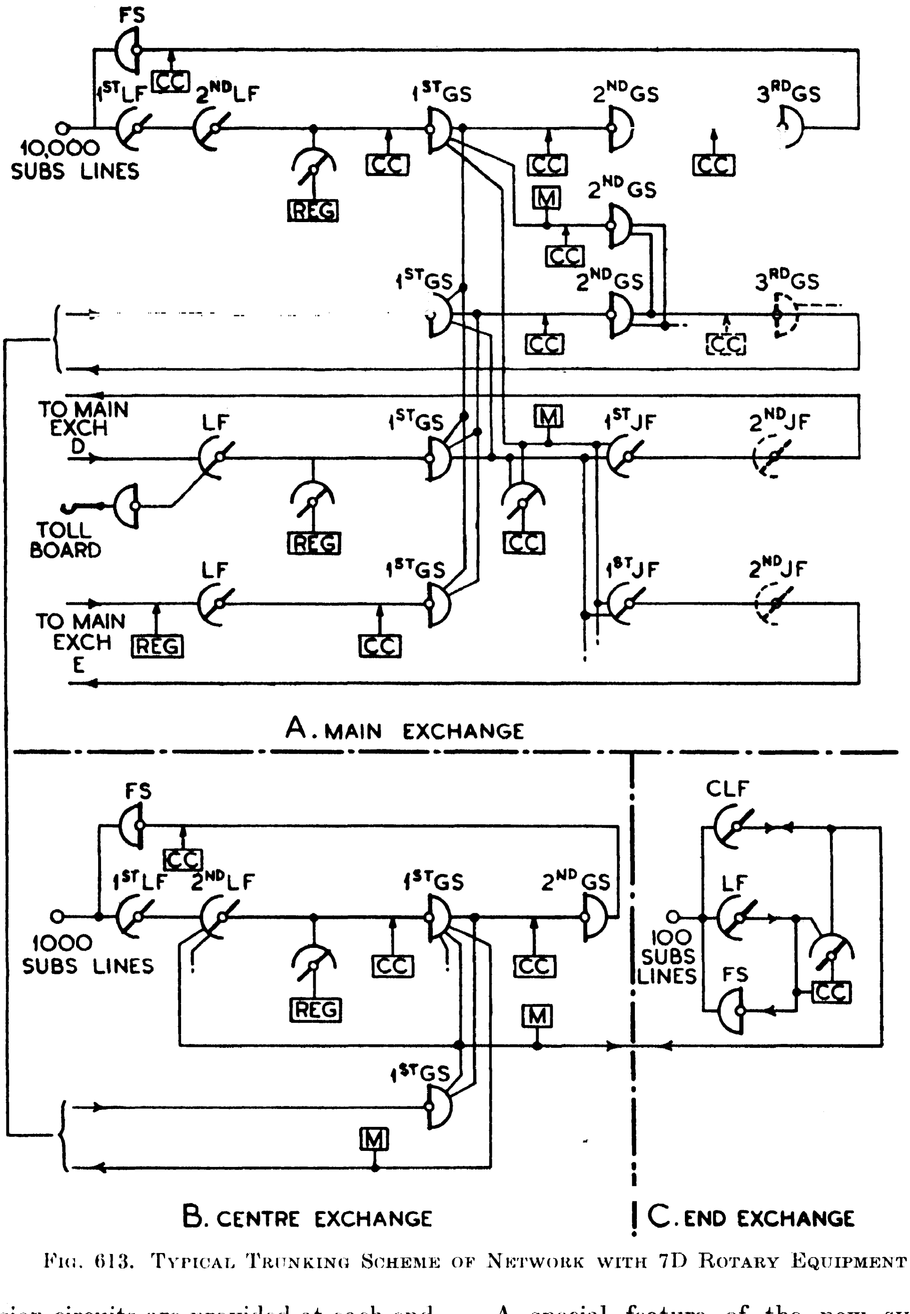


FIG. 613. TYPICAL TRUNKING SCHEME OF NETWORK WITH 7D ROTARY EQUIPMENT

signal conversion circuits are provided at each end of the long junctions.

The 7E System. The No. 7E System constitutes the latest development in the series of Rotary Systems. Fundamentally, the 7E System is a

A special feature of the new system is the subscriber's line circuit which is entirely static, i.e. it does not employ electromagnetic relays. In place of the usual line and cut-off relays, the line circuit consists of a simple moulded plug which is

inserted in a special jack on the M.D.F. The plug contains a group of three or four resistors of the carbon type and a very small metal rectifier. A linefinder start (or call detector) circuit is provided on the basis of one per 50 lines. The start circuit is also extremely simple, the main components being a pair of metal rectifiers, a transformer, a cold cathode tube and a single relay. Fig. 614 shows the principle of the line and start circuits. When the subscriber's line is normal, the potential at point A is -48 V. This potential is applied via rectifier MRA to the centre-point of transformer TRA and is used to bias rectifiers MRB and MRC so that they offer a very high impedance to the 450 c/s tone. When the subscriber's line is looped, the d.c. line current produces a potential drop in the 30 000 Ω resistor so that point A now becomes approximately -24 V. This change of potential reverses the bias on rectifiers MRB and MRC so that they offer a low impedance to the 450 c/s tone applied via the common transformer TRB. This tone is impressed upon the control electrode of the cold cathode tube CC, and operates relay ST. Contacts of ST in turn initiate search for the calling line. When the first linefinder seizes the calling circuit, a low resistance battery is applied to the P-wire and restores the potential at point A to approximately -48 V. The transmission loss introduced by the resistors permanently connected to the speaking conductors is of the order of 0·1 to 0·25 db depending upon the resistance of the subscriber's loop.

The motion of all linefinders and selectors is controlled from the register by a system of voice-frequency marking signals. The source of V.F. supply is a common 3-phase generator supplying 450 c/s at 10 V between each phase and earth. By the use of various transformers, this primary supply is sub-divided into 24 distinctive V.F. signals. The signals are arranged in two groups of 12, one group having a voltage of 3 and the second group a voltage of 5. The 12 sources of each group mutually differ in phase angle by units of 30°. The register contains a "comparator" consisting of cold cathode tubes. One of the 450 c/s tone sources is applied to the comparator from the impulse receiving switches in the register. The circuit is arranged so that the search of the main selectors is arrested when an identical supply is encountered by the wipers.

THE PANEL SYSTEM

The panel system was designed by Messrs. Western Electric Company to meet the needs of large metropolitan areas. It has been extensively developed by the Bell System for providing automatic telephone service in large city areas. The first exchanges were placed into service in 1921, and at the present time there are almost 500 panel type exchanges installed in some 26 different cities throughout the U.S.A.

The panel system is a power-driven revertive impulse system and derives its name from the fact that it employs selectors, the contact banks of which take the form of flat vertical panels. Each selector has access to a total of 500 outgoing

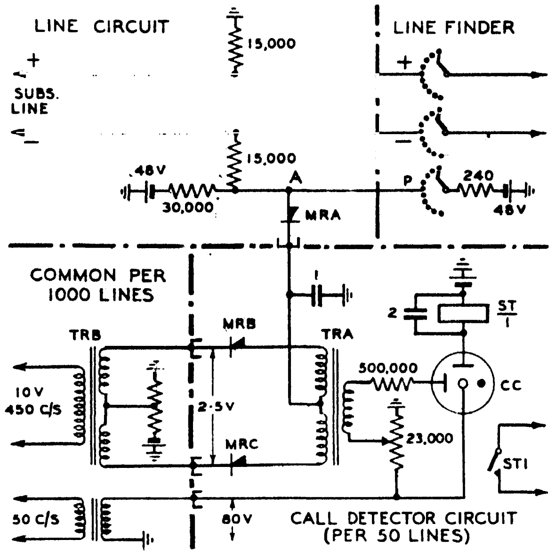


Fig. 614. Principle of Subscriber's Line Circuit No. 7E Rotary System

trunks, but hunting time is minimized by the adoption of multiple brushes and an ingenious system of tripping one out of five contact brushes.

Bank Assembly. The selector bank is made up in the form of a rectangular block from which the contacts project on both sides. There are the usual 3 conductors per trunk, and the assembly is such that every trunk appears 30 times on each face of the bank, i.e. the complete bank unit will accommodate up to 60 selectors. Each bank assembly has a total of 100 circuits—placed one above the other—and the complete selector frame accommodates 5 such banks. The wipers (or brushes) of the selector mechanisms move vertically up the bank and hence have access to a total of 500 outgoing trunks. The construction of the panel selector banks is interesting. Each bank unit is assembled by piling up long horizontal metal strips with insulating strips between them. The metal strips are stamped out so that they form not only the bank contacts on both sides of the frame, but also the multiple connexions between the 30 vertical rows. Soldering tags are

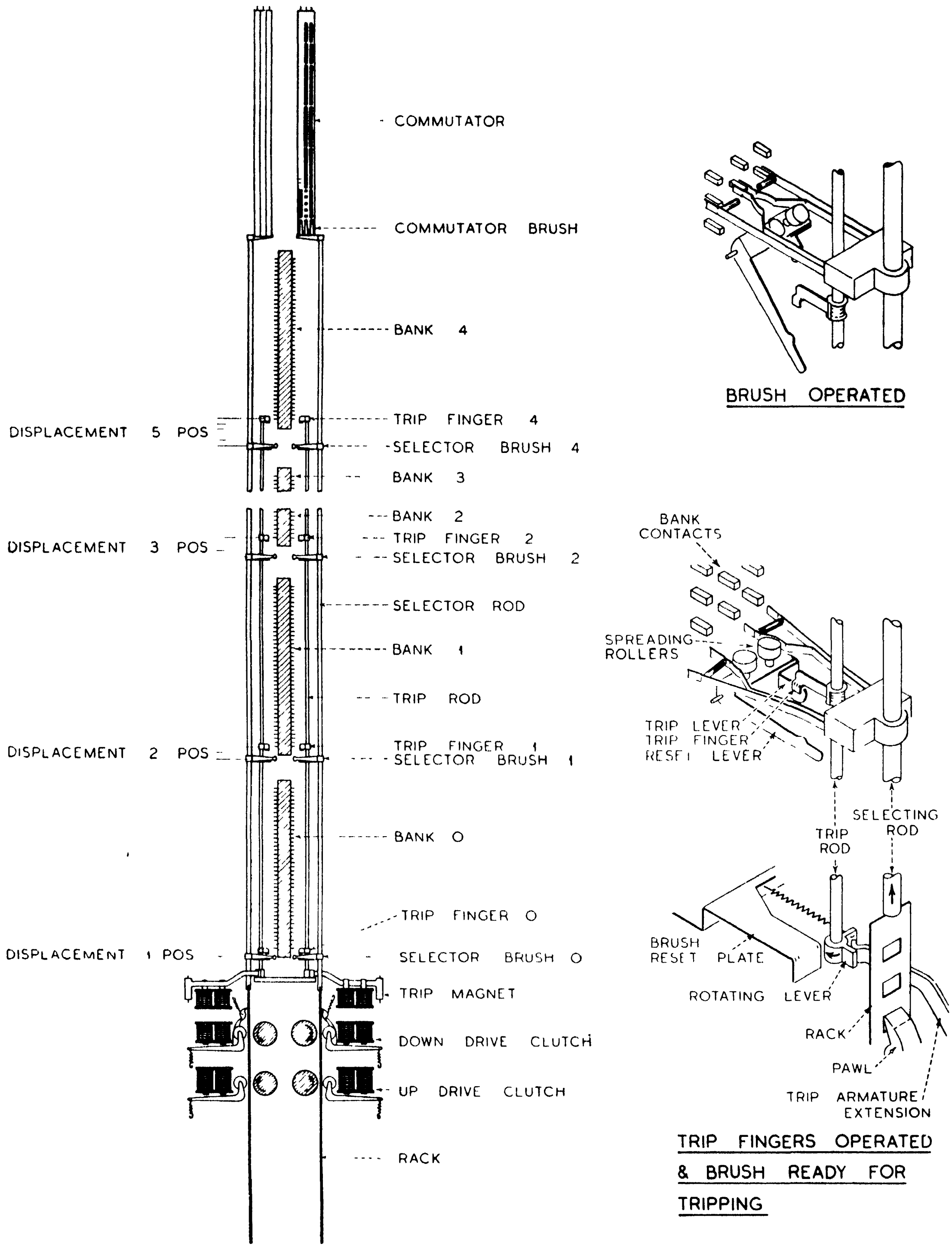


FIG. 615 MECHANICAL ARRANGEMENTS OF PANEL SELECTOR (DIAGRAMMATIC)

provided at each end of the strips for the termination of the outgoing cables. In order to simplify the cabling, it is usual to arrange for successive sets of connexion tags to appear on opposite sides of the bank.

The same type of bank is used at all switching stages with the exception of the linefinder, which has 4 bank contacts per line.

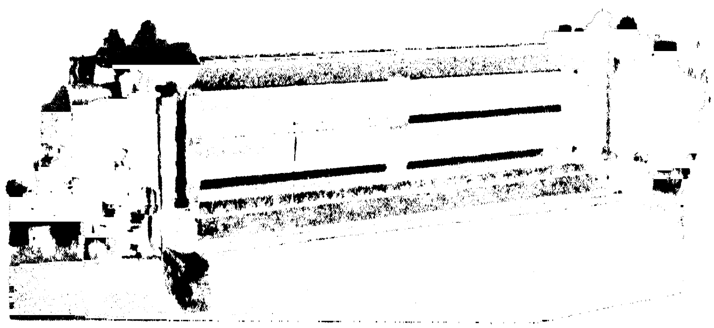


FIG. 617. DRIVE ROLLER UNIT FOR SELECTOR FRAME

The Panel Selector. The mechanical arrangements of the panel selector are shown diagrammatically in Fig. 615. This illustration represents an end view of a selector frame and shows one selector on each side of the frame. Towards the bottom and on each side of the frame there are two cork covered rollers which revolve continuously in opposite directions. Long selector rods are arranged vertically in front of each appearance of the bank contacts. These selector rods terminate at their lower end in a flat strip of metal which can be pressed into contact with either of the two rollers by the operation of the down-drive or the up-drive clutch magnets. It is thus possible to make the selector rod move upwards or downwards depending upon which electromagnet is operated.

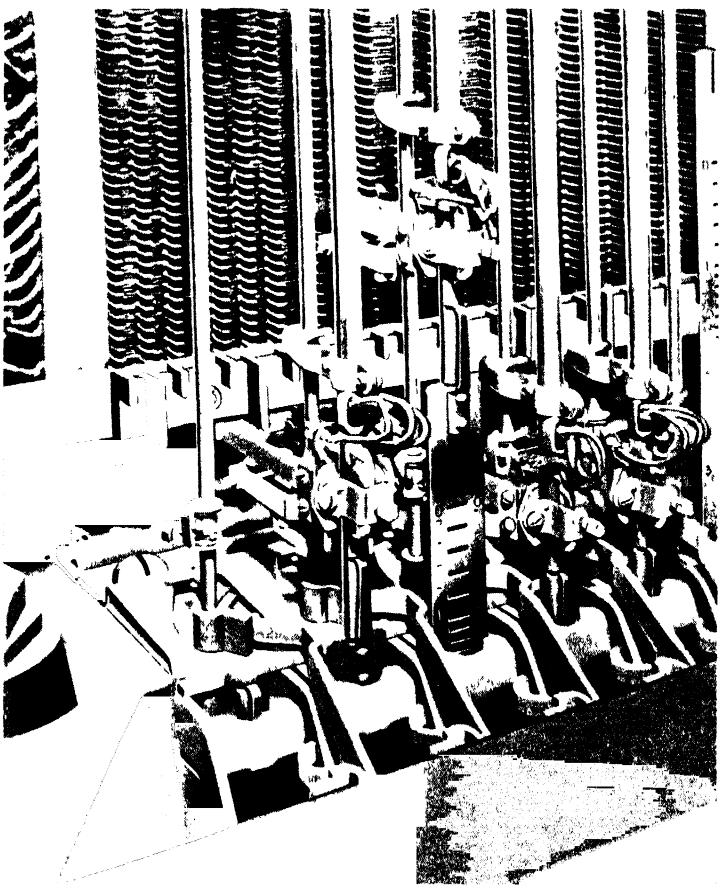


FIG. 616. CLOSE-UP OF LOWER PART OF PANEL SELECTOR

A spring-loaded pawl normally engages with small horizontal slots in the rack of the selector to prevent the selector rod from falling after it has been moved up to any required position. The operation of the down-drive clutch withdraws the pawl from engagement with the rack at the same time that it presses the rack into contact with the down-drive roller. There are 5 sets of wipers or brushes on each selector rod. These brushes are spaced so that each brush assembly is opposite one of the 5 units of the bank. The brushes are normally held clear of the bank contacts by means of a pair of insulated rollers, but any one of the 5 brushes can be "tripped" as required to make contact with the bank.

There is a 6th brush at the top of the selector rod which engages with a vertical commutator panel mounted above the bank assembly. This commutator panel is provided, firstly to provide the necessary connexions to the brushes (all 5 of the main brushes are wired in parallel) and, secondly, to send back impulses to the sender for the control of the selector movement.

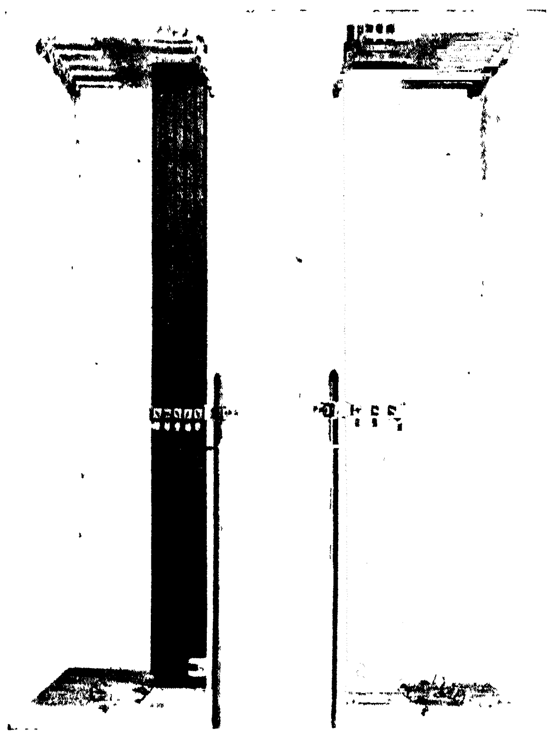


FIG. 618. COMMUTATOR PANEL

A second vertical rod, known as the trip rod, is mounted parallel with the selector rod and between it and the bank assembly. This rod is arranged to rotate through an angle of some 90° under the control of a trip magnet. The trip rod has 5 small projections (or trip fingers) which are connected to the rod through a coiled spring mounting. The trip fingers are placed above the normal position of each brush but below the level of the lower terminals of the corresponding bank. The trip fingers are not all at the same distance from the selector brushes, but are displaced by varying distances as shown in Fig. 615. The bottom trip finger has a displacement of 1 vertical step from its brush, whilst the 2nd, 3rd, 4th, and 5th trip fingers are respectively 2, 3, 4, and 5 vertical steps displaced from their associated brushes.

Although the selector has an availability of 500, the arrangements are such that only the brush associated with one particular group of 100 trunks is brought into use on any call. This preselection of the correct brush is obtained by an initial movement of from 1 to 5 vertical steps under the control of the sender. After this preliminary movement, the trip magnet is operated. The upward movement of the selector rod now continues, and the trip lever of the correct brush engages with the operated trip finger to trip one of the 5 brushes. This particular brush now engages with the vertical row of bank contacts. The vertical movement may be controlled from the sender by means of the impulses reverted back from the commutator panel during vertical movement. Under hunting conditions, on the other hand, the selector rod may continue its upward movement until a free trunk in the selected group of 100 is encountered.

The operation of the brush tripping mechanism can perhaps be followed more clearly by considering a specific example. Let it be assumed that the selector is required to search for a free trunk in

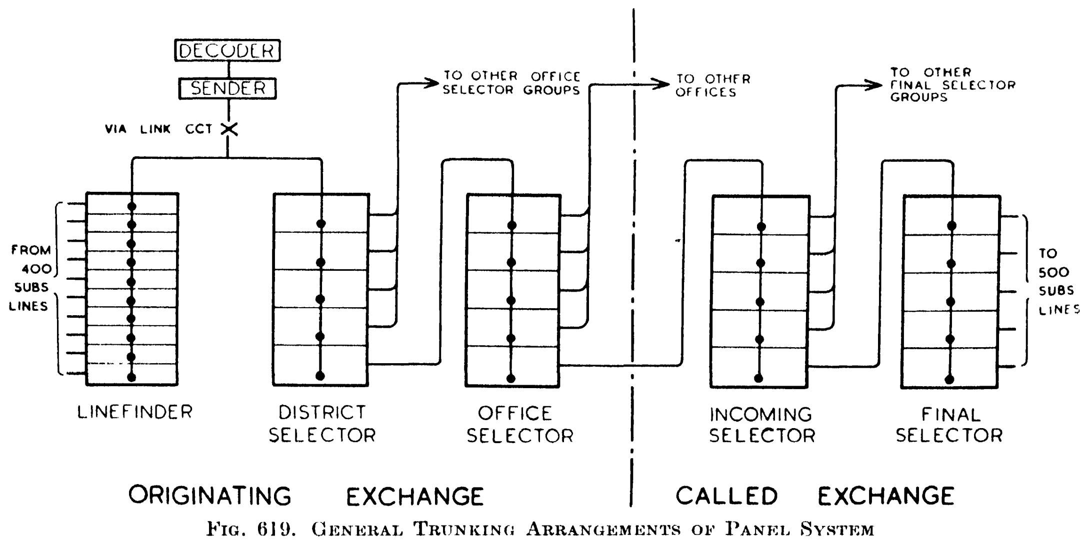


FIG. 619. GENERAL TRUNKING ARRANGEMENTS OF PANEL SYSTEM

the second bank from the bottom of the frame. This is bank No. 1. When the selector is taken into use, the up-drive clutch is operated, but when it has moved the equivalent of 2 vertical steps (i.e. when 2 reverted impulses have been sent back to the sender) the drive is disconnected. The trip magnet is now energized, and, by rotating the brush springs away from the bank contacts. A brush once tripped remains in this position until the selector rod returns to normal. A re-set lever now engages with a brush re-set plate to restore the brush unit to its untripped position.

Fig. 616 shows the lower part of a group of panel selectors whilst Fig. 617 shows a typical

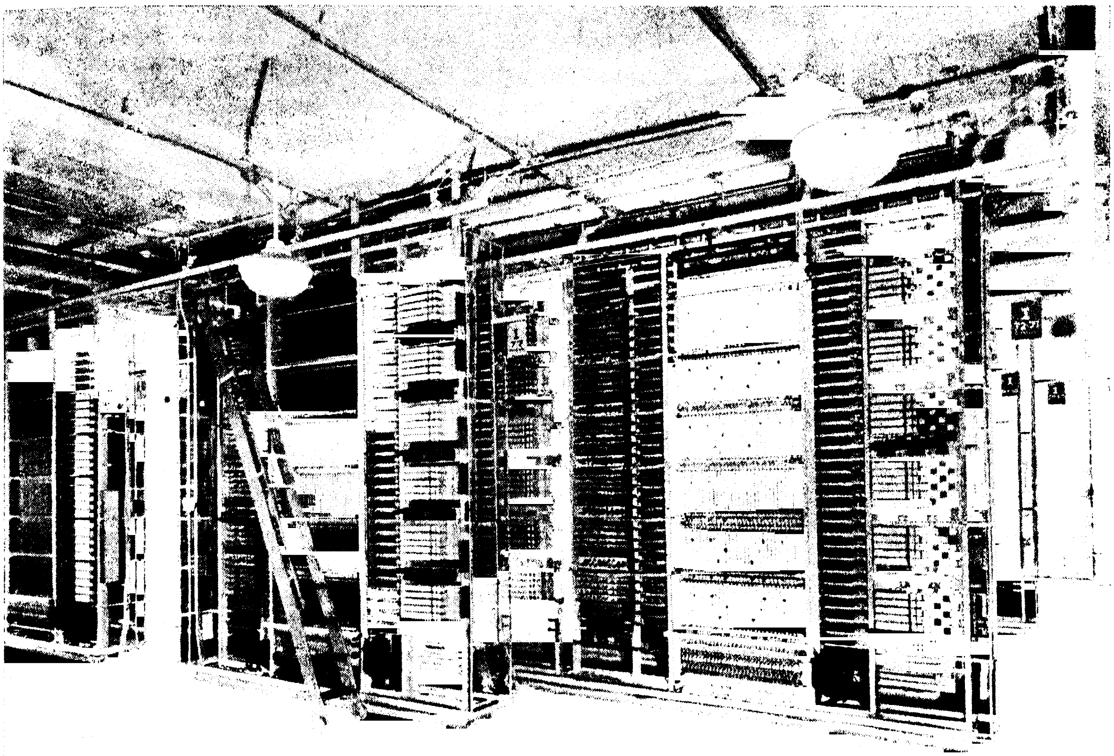


FIG. 620. GENERAL VIEW OF PANEL EXCHANGE

trip rod, rotates all the trip fingers. The trip finger associated with bank 0 moves *below* its associated brush and cannot possibly affect the latter. The trip finger of bank 1 engages with and is arrested by the trip lever of the brush assembly associated with this bank. The trip fingers of banks 2, 3, and 4 are *above* their respective brush units and rotate to such a position that, when the brushes pass them at a later stage, the trip finger will be clear of the trip levers. When the second stage of vertical movement commences, the trip lever of brush 1 presses against the trip finger, thereby withdrawing the rollers which normally hold the drive roller unit removed from the selector frame. Fig. 618 indicates the construction and general arrangements of the commutator panel.

Trunking Arrangements. Fig. 619 shows the general trunking arrangements of the panel system. When a subscriber lifts his receiver, a linefinder searches for the line and extends it via a link circuit to an idle sender. Dial tone is returned to the caller from the sender. The line-finder frame gives access to a total of 400 subscribers' lines. The subscriber then dials the desired number which is recorded and stored in the sender. In large city areas the number consists

of 2 or 3 preliminary digits (office-code digits) which are necessary to determine the routing of the call. As soon as the office-code has been dialled, the sender seizes an idle decoder circuit. The decoder returns signals to the sender to inform the latter of the correct routing, the type of equipment at the distant exchange, etc.

The switching train at the originating exchange normally consists of a *district selector* and an *office selector*. The district selectors are directly connected to the linefinders and under the control of the sender proceed with the process of selection. The first stage in this process consists of tripping the correct brush so that search will be made over the desired bank of the selector. The selector is then moved up to the first terminals of the proper group of trunks, and finally the selector tests these trunks until a free outgoing circuit to the next stage is found.

The trunks from the district selector terminate on an office selector frame. This office selector now moves under the control of the sender to find a free junction in the selected outgoing group. At the incoming exchange the junctions are terminated on incoming selectors. Selection of the required number is normally possible in two stages of selection, i.e. by the use of incoming and final selector frames. Each final selector frame has a capacity for 500 subscribers' lines. In a 10 000-line exchange, therefore, there will be 20 final selector groups. Thus, the incoming selector is required to give access to 20 separate groups which permits of a trunking scheme with an availability of 25 ($25 \times 20 = 500$).

When the call has been established, the sender and link circuit are released, the ringing of the called subscriber's bell being controlled by the incoming selector.

Facilities are provided in the sender and decoder so that, when a call is to be routed to a manual exchange, the correct code pulses are passed out over the junction to operate the call indicator equipment on the manual exchange B-position.

Fig. 620 gives a general view of the apparatus room of a panel exchange.

EXERCISES XX

1. Explain, with the aid of sketches, how it is possible to position a power-driven selector by means of a "revertive impulse" system of control. What are the advantages of such a method and in what circumstances is it used?

2. Discuss the merits and limitations of an automatic system where the selectors are driven by means of a common system of rotating shafts. How is such a power-driven selector associated with the driving shaft when wiper movement is required?

3. Describe the construction and method of operation of the Ericsson 500-point selector. Would it be possible to design a step-by-step selector to give similar movements, and would such a selector have any merits over the normal 2-motion Strowger switch?

4. Explain, with the aid of suitable sketches, the manner in which the correct group of trunks is selected in a group selector of the Rotary System.

5. Describe how the brushes of a final selector in the Rotary System can be directed to a particular line on the bank.

6. Give a typical trunking diagram of a Rotary System with registers. How are these trunking arrangements modified in very small exchanges?

7. Describe how, in the Panel System, any required trunk on a 500-outlet selector can be seized by not more than 100 "steps."

8. Draw a typical trunking diagram of a large city exchange using the Panel System of selection. Why is this system particularly suitable for use in a congested metropolitan area?

9. Give a list of the fundamental differences between the Siemens No. 17 and the Rotary Systems. State briefly what you consider are the merits and the limitations of these two systems.

10. In a certain Panel exchange, the total busy hour traffic on a certain group of "office selector" frames is 160 T.U. Calculate the number of frames required to carry this traffic, and the total number of selectors which should be fitted to these frames. It may be assumed that full availability conditions exist between the district selectors and office selectors, and that a grade of service of 0·002 is required.

CHAPTER XXI

RELAY AND CROSSBAR SYSTEMS

In all the switching schemes described in earlier chapters, connexion to the required line is obtained by the use of "mechanisms," by means of which one incoming circuit can be directed to any required line in a group of outgoing circuits by the positioning of "wipers" (or "brushes") on a bank of contacts.

Such mechanical switching schemes have certain inherent limitations. In the first place, it is economically impracticable to provide precious metal contact surfaces between the wipers and the bank contacts. This in turn necessitates maintenance attention at fairly frequent intervals (bank cleaning, etc.) to ensure that good and noise-free electrical contact is obtained. A moving system of wipers also requires flexible wiper cords or collector brushes, and these also are a potential source of faults. The mechanisms themselves require regular lubrication and periodical inspection for wear. Apart from these considerations, however, the utilization efficiency of a selector is very small indeed. A 200-outlet selector, for example, requires an elaborate positioning mechanism which is in use only for a very short period during the setting of the wipers. Once the mechanism has been positioned, only one of the 200 sets of bank contacts is of use.

Ever since the advent of automatic telephony, the development of a system which would not require multi-outlet mechanisms has always been an attractive line of investigation. In the past the only practicable alternative switching medium has been the use of electromechanical relays, and various systems have been designed in which all the switching operations are effected by means of simple relay actions. Unfortunately most of these switching systems became somewhat complex when applied to large telephone networks. In recent years the development of the "crossbar selector"—which is a special form of multiple relay with selective operation of the contact springs—has reopened the interest in relay switching methods.

This chapter describes the broad principles on which relay and crossbar switching schemes are based, and concludes with some observations on possible future developments in switching methods.

THE RELAY SYSTEM

As implied by the title, this system is one in which all switching operations to provide communication between subscribers are made solely by ordinary electromagnetic relays. Apart from the relays themselves, there are no other moving parts in the system. The Relay System tends to become somewhat complex when it is applied to large exchanges, and for this reason its use (in this country) has been mainly restricted to Private Automatic Branch Exchanges. There is one public exchange at Fleetwood working on the Relay System.

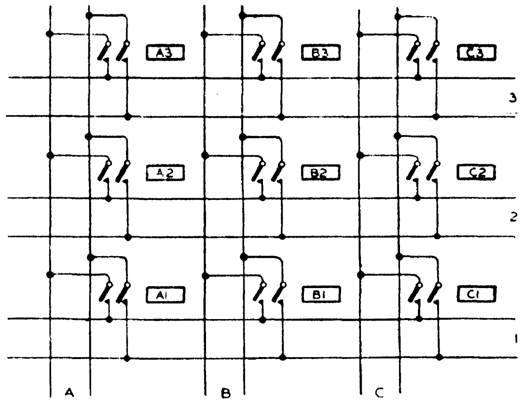


Fig. 621. Simple Relay Scheme for Connecting any one of Three Lines to Three Alternative Outlets

The general principles of relay switching are considered in the following paragraphs. The application of these principles to P.A.B.X. working is examined later in Chapter XXIV.

General Principles of the System. A simple method of interconnecting lines by means of relays is illustrated in Fig. 621. This circuit enables any one of three lines A, B, or C to be connected to any selected one of three other lines 1, 2, or 3 by the operation of one relay. Thus the operation of relay $B2$ connects line B to circuit 2.

This simple switching scheme requires nine relays to connect any one of three lines to one of three outlets. It could be adapted to provide intercommunication between three subscribers' lines by arranging that the subscribers' circuits appear both on the vertical and on the horizontal paths. Under these conditions a total of six relays will suffice to connect any one line to either of the two remaining lines. (For example, if subscribers A, B, and C are connected to the horizontal paths

1, 2, and 3 respectively, relays $A1$, $B2$, and $C3$ *are no longer* required.)

The straightforward system of co-ordinate

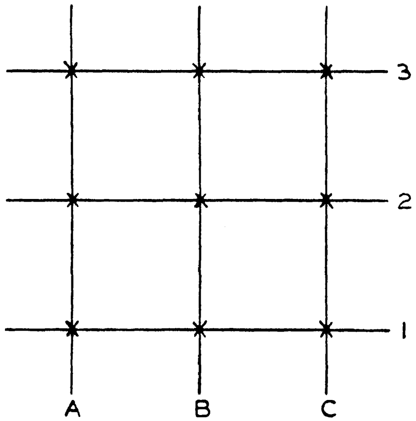


Fig. 622. Diagrammatic Representation of the Conditions of Fig. 621

switching illustrated in Fig. 621 can be developed to provide switching facilities between a larger number of lines by the provision of additional relays, but the total number of relays required increases rapidly as the number of lines grows. If the number of lines is N, then the total number of relays is given by $N(N-1)$. Thus, a 1000-line exchange would require just under 1 million relays to provide complete facilities for interconnexion. Apart from the impracticability of providing such a large number of relays, the scheme is clearly very inefficient. A considerable number of switching relays would be used only on rare occasions, and some of the relays might never be required at all. Moreover, this simple cross-connecting scheme involves the provision of extensive apparatus in each subscriber's line to provide facilities for ringing, transmitter current supply, metering, and so on. It is clear, therefore, that, for a relay switching scheme to be economically practicable, some modification to the above switching principles is required.

Before proceeding further with the development of the idea of relay switching, it is desirable to introduce some convention which will show the cross-connecting arrangements of Fig. 621 in a much simpler form. The usual convention is shown in Fig. 622 where an X at the point of intersection indicates that there is a relay at this point which is capable of switching the horizontal to the vertical lines.

Full Availability. A much more practical scheme of switching is illustrated in Fig. 623. For simplicity, it is assumed that there are 10 subscribers' lines. The theoretical maximum number of simultaneous conversations in such an exchange is, of course, five, but in practice the probability of all lines being simultaneously engaged is extremely

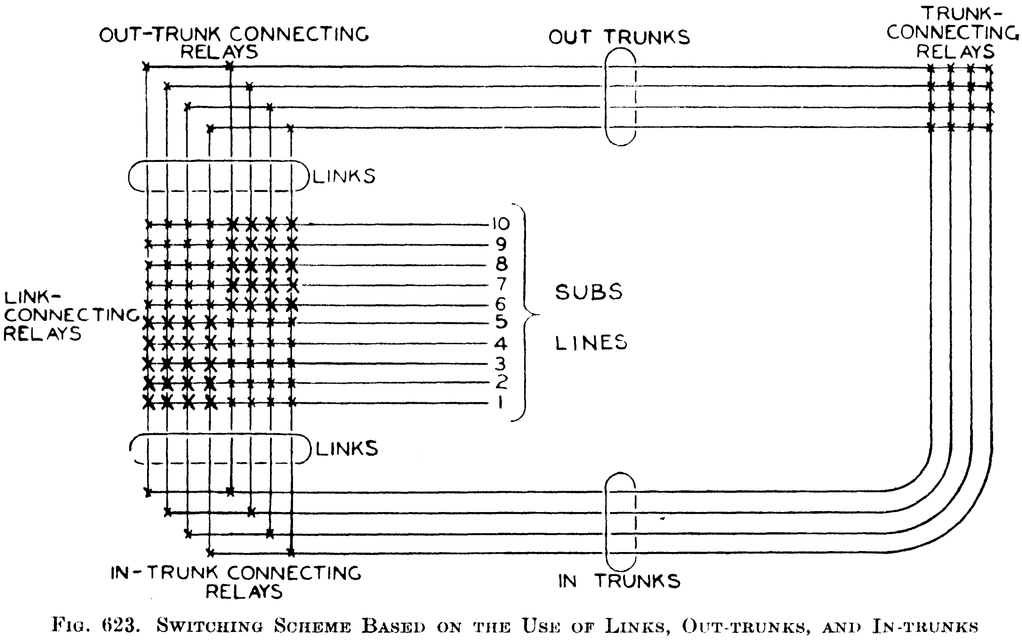


Fig. 623. Switching Scheme Based on the Use of Links, Out-trunks, and In-trunks
(Note full availability conditions)

remote. Under all normal conditions a good grade of service can be given if the equipment is designed to cater for, say, three or four simultaneous calls. It is necessary, therefore, to provide only sufficient connecting circuits to meet the anticipated maximum volume of traffic during the busy hour of the exchange. In Fig. 623 it has been assumed that the maximum traffic requirements can be met by the provision of four common connecting circuits to serve the whole of the subscribers. Each circuit is composed of two parts, an outgoing portion which is accessible to the calling subscriber, and an incoming portion which gives access to the called subscriber. Facilities are provided to interconnect the "out-trunks" and the "in-trunks" as required by a group of "trunk-connecting relays."

Access between the subscribers and the common trunks is provided by "link" circuits. Each link has access to one particular "out-trunk" and one particular "in-trunk" (but not to both at once). Thus on a complete connexion two links are used, one for the outgoing side and the second for the incoming side. The number of links required is therefore equal to twice the number of simultaneous calls (i.e. in the case under consideration a total of 8 links is necessary). Relays are required in the subscriber's line circuit to select a free link circuit, and further relays are required to switch the selected link to a free trunk. If it is desired to give full availability (i.e. so that each subscriber has access to every link and every trunk), a total of 96 relays is required for connecting the lines to the links, and the links in turn to the trunks. A further 16 relays are required to interconnect the "out"- and "in"-trunks. The total number of basic switching relays required for a 10-line exchange is 112. Thus, although we are now providing only for a limited number of simultaneous calls, the cost is even greater than the simple switching scheme of Fig. 622 (which requires 90 relays). On the other hand, it is now possible to locate the transmission bridge, the ringing relays, and all other equipment required during the setting up of a call, in the common connecting trunks. There are only four such connecting circuits, and hence considerable economies can be made in the total quantity of relays required for miscellaneous functions. The economies in this direction increase progressively as the size of the exchange is increased.

Limited Availability. We have seen that, out of a total of some 112 switching relays required for a 10-line exchange, 96 of these are necessary to provide access between the subscribers' lines and the common trunk circuits. The number of such relays can be materially reduced by the adoption of a system of *limited availability* between the subscribers' lines and the link circuits, and between the link circuits and the common trunks.

If, in Fig. 623, the link-connecting relays marked in small type (x) are omitted (thereby leaving the relays marked by heavy crosses (**X**)), the first 5 lines would have access only to the first 4 links, and lines 6 to 10 would have access only to the second group of 4 links. This arrangement still provides facilities for a maximum of 4 simultaneous calls, but it does not permit of more than 4 in each group of 5 subscribers' lines being in use at the

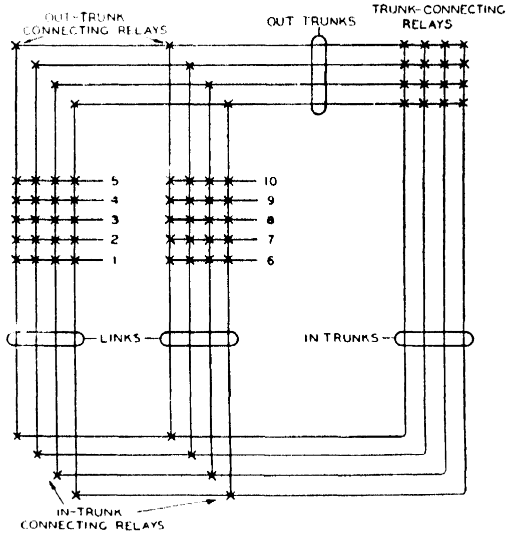


FIG. 624. SHOWING THE SAVING IN RELAYS OBTAINED BY LIMITATION OF THE NUMBER OF LINKS

same time—either on incoming or on outgoing calls. If this limitation can be tolerated, then a total of only 72 relays is required instead of 112 relays which are necessary under full availability conditions. Fig. 624 shows the modified trunking arrangements with limited availability between the subscribers' lines and the link circuits. In the Relay System the subscribers' circuits are arranged in units of 5 lines, and 3 or 4 links may be provided to serve each unit.

Further economies can be obtained by providing limited availability between the links and the main trunks. Fig. 625 illustrates a typical arrangement. A 25-line exchange is now envisaged with the subscribers' circuits arranged in 5 units each of 5 lines. Each subscriber's unit is served by 4 links, which in turn give access to 4 out of 7 common "out"-trunks and "in"-trunks. The connexions between the links and the common trunks are

arranged to equalize, as far as possible, the load on the common link circuits. (In Fig. 625, 6 of the

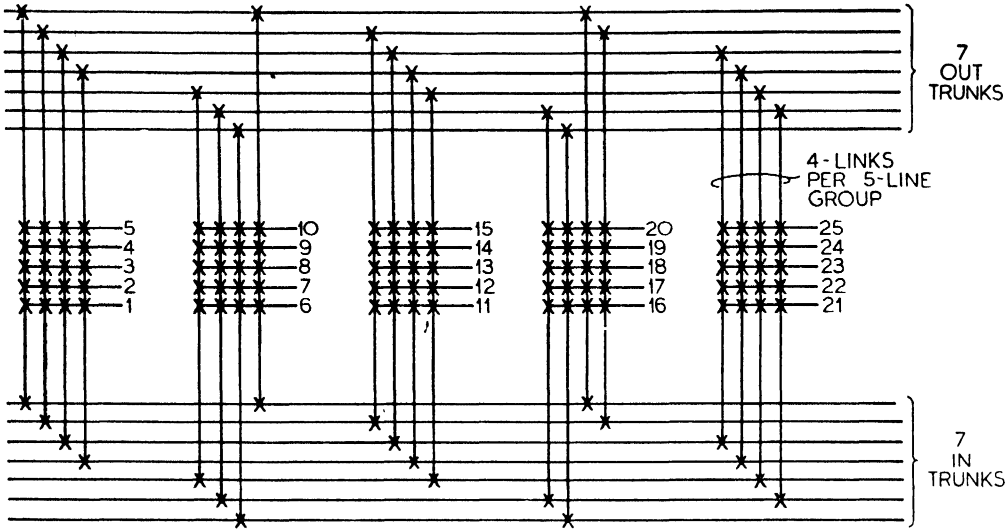


FIG. 625. LIMITED AVAILABILITY BETWEEN LINKS AND TRUNKS

7 trunks are accessible from 3 subscribers' units, whilst one trunk is available from 2 such units.)

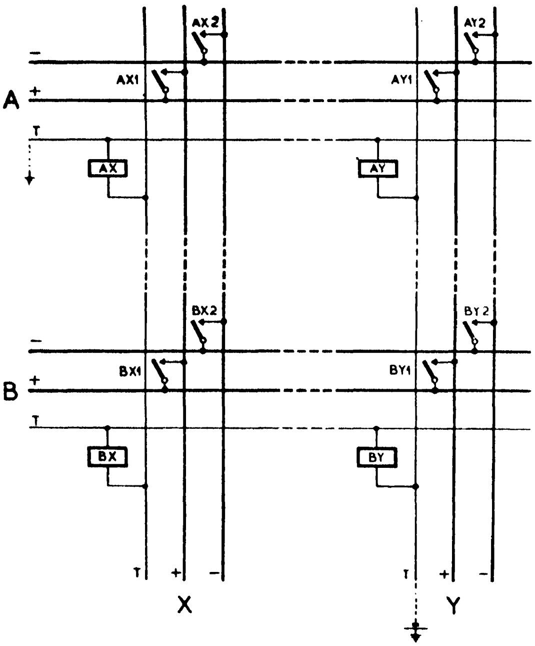


FIG. 626. METHOD OF CONTROLLING SWITCHING RELAYS

A 25-line exchange designed on this basis requires 189 switching relays as compared with a total of some 600 relays which would be required with a simple full availability switching scheme.

Limitation of the availability in the above manner may result in the failure of a call due to:

(*a*) all link circuits serving the subscriber's group being engaged, or

(*b*) all the common trunks which are available to the links being engaged.

In any particular case the number of link circuits, and the accessibility to the main trunk circuits, can be adjusted to give a satisfactory grade of service under conditions of maximum load.

Control of Switching Relays. Fig. 626 shows a common method of controlling the switching operations in a relay system. For simplicity it has been assumed that two circuits (A and B) may require connexion to either of two other circuits (X and Y). To provide these facilities, four switching relays (AX, AY, BX, and BY) are required. Relay AX is operated when it is desired to connect link A with link X, relay BY is operated when link B is to be connected to link Y, and so on.

To effect a particular switching operation, the two circuits must be suitably marked, and these marking conditions must be utilized to operate one particular switching relay. Let it be assumed that it is desired to connect link A to link Y. Earth is applied to the test wire of link A, and thence to relays AX, AY and any other relays in the series. Battery is applied to the T-wire of link Y and to relays BY, AY and any other relays associated with the Y circuit. Only one relay (i.e. AY) receives both the earth condition from circuit A

and the battery condition from circuit Y. This relay now operates, and at contacts $AY1$ and $AY2$ completes the switching of the speaking circuit.

Common Equipment. In addition to the relays required for the switching of one subscriber to another, additional relay groups are necessary to provide transmission, ringing signals, tone signals and to set up the required conditions for the operation of the switching relays. The transmission bridge elements and the supervisory relays are usually sufficient for an exchange of this size. The occupancy time of the marker is still less and one marker is adequate.

When a calling subscriber lifts his receiver, a link connecting relay (LC) connects his line to a free link, and the operation of the out-trunk connecting relay (OTC) extends the line to a disengaged out-trunk and its associated A and B feed. The operation of the OTC relay disconnects the in-trunk connecting relay (ITC) of the link to guard the

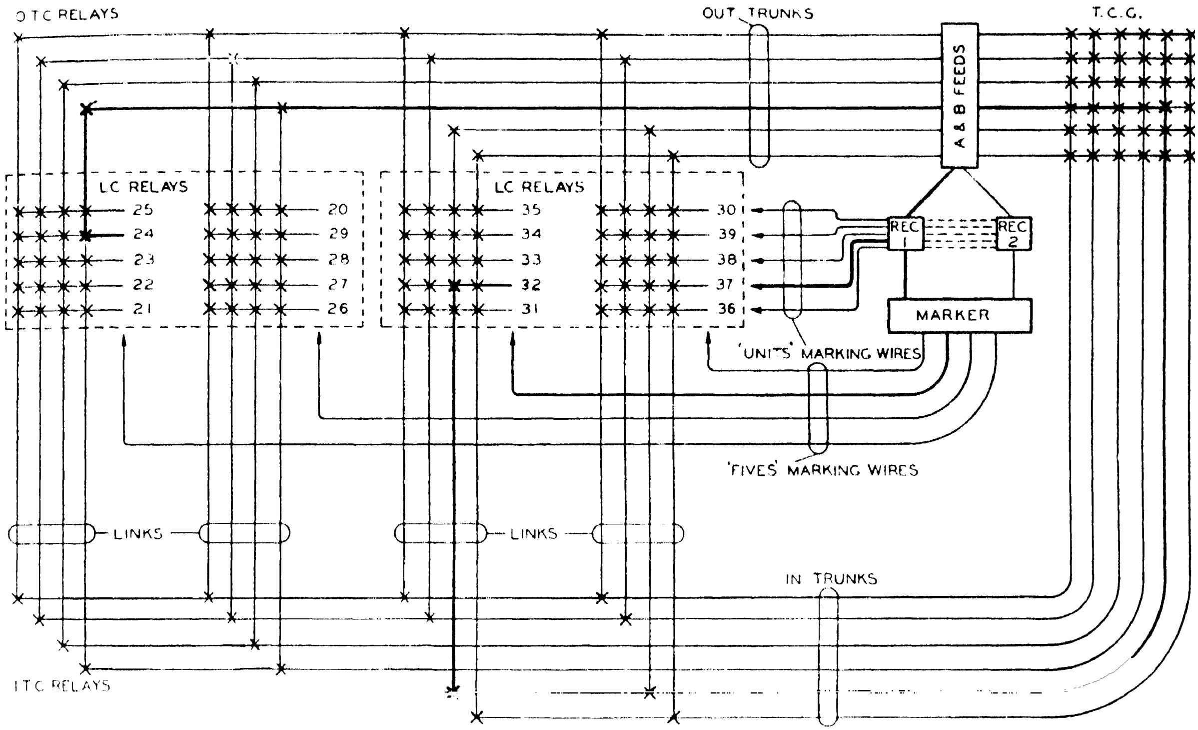


FIG. 627. TRUNKING ARRANGEMENTS OF TWO-DIGIT RELAY SYSTEM
(Heavy lines indicate connexions when subscriber 24 calls No. 32)

accommodated in a unit known as an *A and B feed.* One A and B feed is permanently associated with each "out-trunk." The impulses from the subscriber's dial are counted and stored in a relay group known as a *recorder*, which is connected to an A and B feed circuit as required. As the digits are received, the recorder passes signals to a *marker* which determines the switching relays to be energized for the establishment of the call to the required line.

Setting Up of a Call. Fig. 627 shows the trunking arrangements of a 20-line exchange which is equipped with 6 out-trunks with their associated A and B feeds, 6 in-trunks, and 4 links per subscriber's unit of 5-lines. The recorders are in use only for a very short time, and two such units are call against intrusion. The A and B feed seizes a free recorder and returns dial tone to the calling subscriber. The recorders are provided on the assumption that they will be held only for a very short time, i.e. during dialling. It is therefore not permissible to allow a subscriber to hold a recorder for an appreciable period before he commences to dial. The circuits are, in practice, arranged so that, although an A and B feed extends a caller to a recorder, the recorder itself is not engaged until after the receipt of the first impulse. The recorder can, therefore, be seized by any other calling subscriber at any time prior to the commencement of dialling. The recorder stores the impulse trains on a series of relays and, when dialling is complete, the marker is taken into use. The called line is

now marked as described later. If the required line is disengaged, it is extended to a free link and to an available in-trunk. The trunk-connecting group (*TCG*) now connects the called line to the particular A and B feed which was seized by the calling party. Both the recorder and marker are now released and ringing current is supplied by the A and B feed. This same unit provides the transmission bridge when the called subscriber answers, or busy tone should the called subscriber be engaged.

Marking. Fig. 628 illustrates the principle of marking. On completion of dialling, a battery is applied to the appropriate "units"-marking wire, whilst an earth is applied to the "fives"-marking wire. Each fives-marking wire is terminated on an incoming trunk test (*ITT*) relay, and the units-marking wires are multipled over the whole exchange to the circuits of the corresponding *LC* relays. In Fig. 628 the *ITT* relay of the unit serving lines 31 to 35 (known as the 3(1–5) unit) is shown operated. The units-marking wire which serves all numbers which end in 2 or 7 (known as the (2·7) marking wire) is extended by the contacts of *ITT* to the *LC* relays of line No. 32. These marking conditions cause the first free link to be taken into use by the required line and to be extended to a disengaged in-trunk. Conditions are now established for the operation of the correct "trunk-connecting" relay (*TC*) which switches the out-trunk seized by the calling subscriber to the in-trunk taken up by the called subscriber.

The same marking principle is used on larger exchanges, but the number of "fives-marking" wires is of course correspondingly increased.

CROSSBAR SWITCHING

The principle of crossbar or co-ordinate switching is not new. About the year 1915 the Western Electric Company of America designed a "co-ordinate selector," which consisted of 100 bank contacts arranged in ten rows of 10. The contacts were actuated by 10 vertical and 10 horizontal rotary rods, each rod being controlled by an electromagnet. The switch contacts were placed at the points of intersection between the rods, and a connexion to any one of the 100 outlets was established, first by rotating the vertical rod, and then by the operation of the horizontal rod. The vertical rods were provided with articulated arms, which preselected the required level, and the horizontal arms were fitted with cams which operated the selected contacts.

Credit for the crossbar selector in its present form is probably due to the Swedish Telephone Engineer, Betulander, who, in 1917, in the course of his development of the relay system, designed

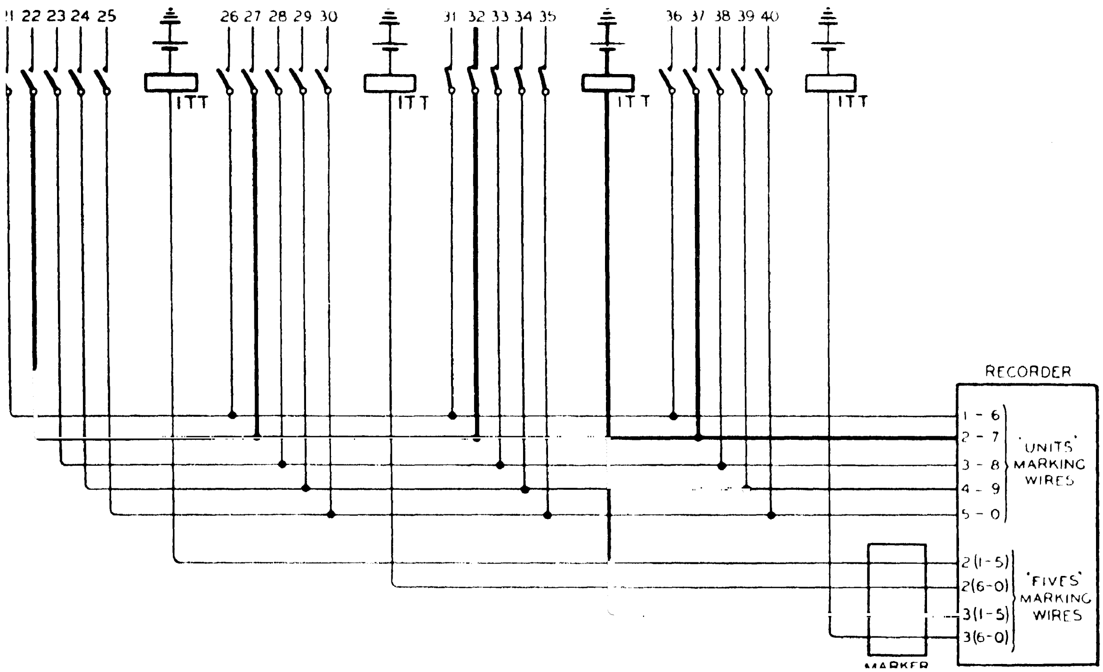


FIG. 628. PRINCIPLE OF MARKING

a co-ordinate selector utilizing relay type contact springs. The idea seems to have remained dormant for some years but, during the last decade, both the Swedish Telephone Administration and the Bell Telephone Company of the United States have developed highly-successful crossbar switching systems. The Swedish and American crossbar standard switch (i.e. with 20 vertical paths) is known as a 200-point switch, whilst the smaller switch gives facilities for 100 switching points and is therefore known as a 100-point switch. The 200-point crossbar switch consists of a rectangular welded frame on which are mounted 20 vertical units, and the selecting mechanism consists of 5

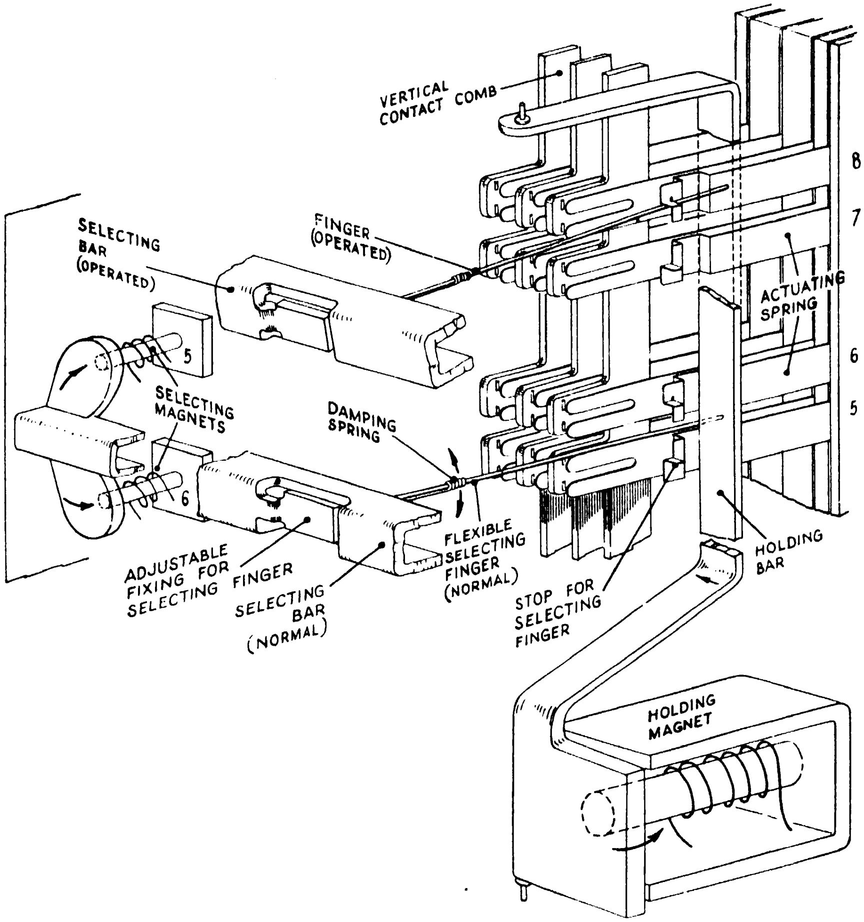


FIG. 629. PRINCIPLE OF CROSSBAR SELECTOR

selectors are substantially similar in design, although there is a number of minor constructional differences.

The Crossbar Switch. The crossbar switch consists essentially of 20 vertical circuit paths and 10 horizontal circuit paths, together with a mechanism for cross-connecting any one of the 20 vertical circuits to any one of the 10 horizontal circuits by the operation of electromagnets. A similar switch with 10 vertical and 10 horizontal paths is also available for use where the larger standard switch would be uneconomical. The horizontal bars each of which can be moved in two directions by the operation of 10 selecting magnets. The switch is some 9¼ in. in height and 30½ in. long.

Each vertical strip of the crossbar switch contains 10 spring sets, each comprising 3 or 4 make contacts depending upon the circuit requirements. The whole switch assembly (200-point switch) therefore contains a total of 200 spring sets.

Any set of contacts may be actuated first by operating the *selecting* magnet corresponding to the horizontal row in which the spring set is located,

and then by energizing the *holding* magnet associated with the appropriate vertical row. The design of the switch mechanism is such that once a particular spring set is operated, it can be held

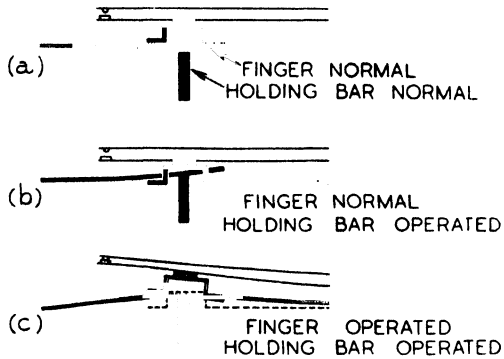


FIG. 630. METHOD OF OPERATING SPRING SETS ON CROSSBAR SELECTOR

by the energization of the holding magnet alone, the selecting magnet being energized only momentarily during operation. Hence, after the selecting magnet is released, other calls may be established the horizontal paths into two or more sections, and in these circumstances the number of simultaneous calls which it is possible to establish on one switch is even greater.

Fig. 629 shows in diagrammatic form the principle of operation of the crossbar switch. For simplicity two horizontal selecting bars and two selecting fingers only are shown, and only 4 adjacent spring sets of one vertical bar have been included. In actual practice there are, of course, 5 selecting bars with a total of 100 selecting fingers and 200 spring sets. Let it be assumed that it is desired to operate the No. 6 spring set of Fig. 629. The operation of selecting magnet "6" tilts the selecting bar so that the selecting finger moves upwards over the flanges of the actuating spring and comes to rest against the projecting stop. Attached to the armature of the holding magnet is a vertical holding bar which normally moves into the recess of the actuating spring and hence does not operate the spring pile (Fig. 630). When, however, a selecting finger is moved from its normal horizontal position by the operation of the selecting bar, the outer extremity of the selecting finger bridges the recess in the actuating spring so that, when the

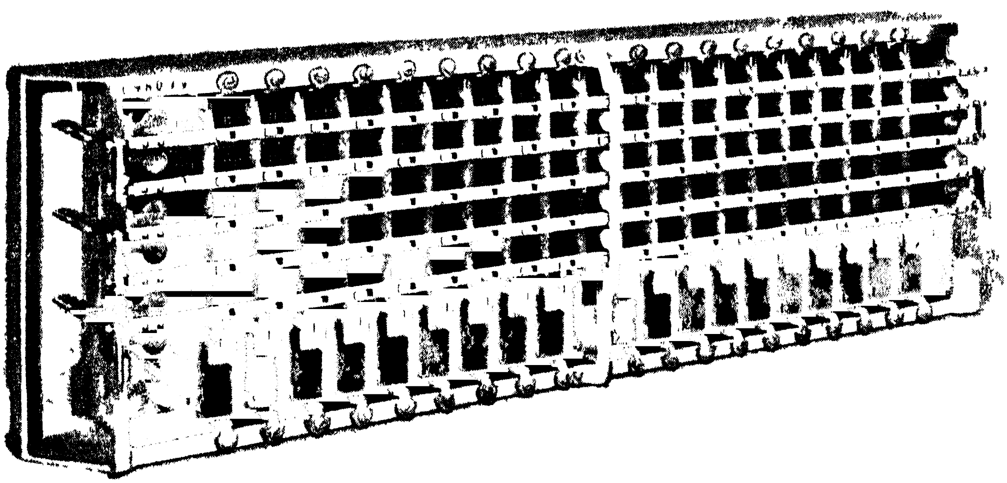


FIG. 631. GENERAL VIEW OF 200 POINT CROSSBAR SELECTOR

through the same switch by the operation of the same or other selecting magnets and the appropriate holding magnets. It is clear that a maximum of 10 connexions can be established through one switch, i.e. one call through each of the horizontal paths. As will be seen later it is possible to divide holding bar is operated, it comes into contact with the operated selecting finger, and thereby actuates the appropriate spring set. The selecting finger is now held between the holding bar and the actuating spring by the pressure exerted by the holding magnet. The selecting finger is very flexible, and

although the extremity of the selecting finger may be clamped by the holding bar, this does not prevent the selecting bar from restoring to normal under the action of its controlling springs when the selecting magnet is de-energized. By this arrangement the selected spring pile on the crossbar switch is held actuated by the operation of the holding magnet alone, and the selecting bar may be used again for the positioning of other selecting fingers to establish subsequent calls. At the end of the call the release of the holding bar allows the selecting finger to restore to its normal horizontal position clear of the actuating springs. A damping spring is provided on the selecting finger to prevent excessive vibration during operation and release.

Fig. 631 gives a general view of the 200-point crossbar switch. To effect economy of space, 3 pairs of the selecting magnets will be seen at the left-hand side of the horizontal connecting bars, whilst the remaining 2 pairs of selecting magnets are shown at the right-hand side of the switch frame. The 20 vertical contact units with their

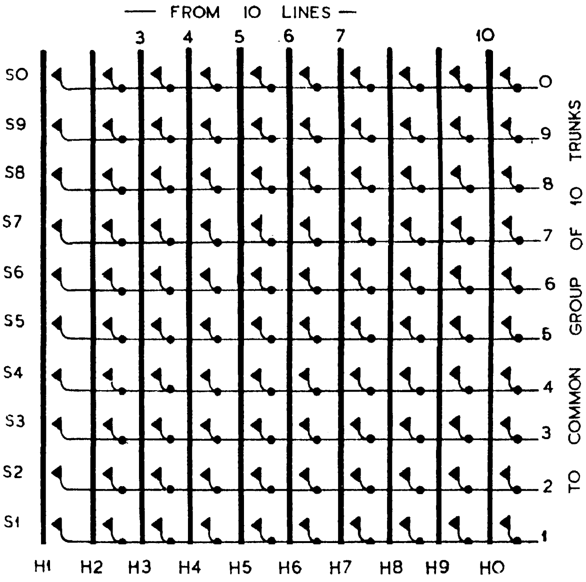


FIG. 632. CROSSBAR SELECTOR USED TO PROVIDE ACCESS FROM TEN INCOMING LINES TO A COMMON GROUP OF TEN OUTGOING TRUNKS

holding magnets at the bottom are also clearly visible.

The vertical units, containing the spring sets, the holding magnet, and the holding bar, are fixed to the switch frame by means of 2 screws and are readily detachable. Particular regard has been paid to the manufacture and wiring of the spring piles. In most applications of the switch, one spring of each make contact is commoned to all similar springs in the same vertical. In order to reduce the amount of wiring, these springs are stamped out as a single "comb" with wiring tags at the lower end. The remaining contact springs

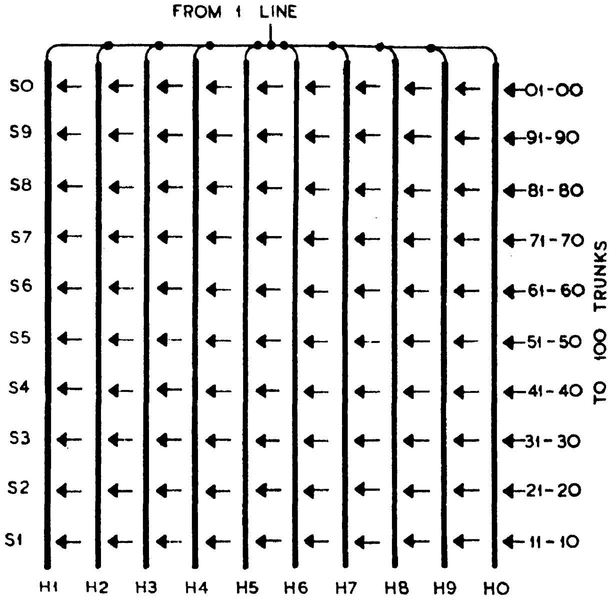


FIG. 633. CROSSBAR SELECTOR ARRANGED AS SINGLE 100-POINT SWITCH

are, of course, individual to the particular spring piles and are taken out to connexion tags at the rear of the switch. These connexion tags are designed so that similar springs in the various vertical units can be commoned together by the use of horizontal bare tinned copper conductors.

The contact springs are split at their free extremities and are fitted with twin contacts. The contacts themselves are of nickel in the form of a bar or *ribbon* across the face of the contact spring. The nickel contact ribbons are coated with a thin layer of palladium and are arranged so that when 2 springs are placed into contact with each other, their associated contact ribbons are at right angles to each other. This arrangement provides a considerable tolerance in the manufacture and adjustment of the spring sets.

The crossbar switch can be provided with off-normal contact spring assemblies. When required, these springs are associated with each holding magnet and are operated like ordinary relay contacts when the magnet is energized.

Methods of Using Crossbar Selector. One of the main advantages claimed for the crossbar selector is its versatility. From a trunking point of view,

a 100-point crossbar selector can be considered as a unit containing 10 individual selectors, each selector having 10 outlets. Similarly, a 200-point crossbar switch is equivalent to 20 simple 10-point selectors.

One obvious way of utilizing this selector is to multiple the connexions of the vertical bridges so that the switch is equivalent to a shelf of ten 10-point uniselectors with a common multiple. Fig. 632 shows this simple arrangement. (For clarity a 100-point selector is assumed, but the same principle can be applied to the normal 200-point unit.) This illustration shows that 10 incoming lines can be connected to the 10 vertical bridges of the switch, whilst a common group of 10 outgoing trunks can be provided from the multipled horizontal connexions. Thus, any incoming line can be connected to any required line in the outgoing group of 10 by the operation, first of the correct selecting magnet, and then of the hold magnet in the appropriate vertical bridge. A switch arranged in this manner could provide for a maximum of 10 simultaneous calls, provided that each call is routed to a separate outgoing trunk.

At the other extreme, the 100-point crossbar switch can be used to give access from one line to any one of 100 outlets. In these circumstances (Fig. 633) the horizontal multiple between the vertical bridges is omitted, so that each of the 10 bridges has access to 10 separate outlets. It should be noted that each bridge has still access only to 10 outlets and, if a 100-outlet selector is required, it is necessary to common together all the 10 bridges as shown. With such a scheme it is possible to operate a specified pair of select and hold magnets in order to switch the line to any required outlet. It is clear that with the crossbar switch arranged as a simple 100-point selector, not more than one call can be passed through the selector at the same time.

Apart from the two extreme cases described above, it is possible to provide any intermediate arrangement by strapping together two or more vertical bridges as required. For example, it is possible to arrange a 100-point crossbar switch to behave as two separate 50-point selectors by commoning the bridges as two groups of 5. It must be clearly understood that, as the availability is increased, so the number of incoming lines which it is possible to switch to these trunks is correspondingly decreased. With a crossbar switch of given design, the product of the number of incoming lines and the number of outgoing trunks is constant and equal to the total number of switching points on the selector (i.e. 100 or 200). The selector can be commoned to give an availability of from 10 to 100 (or 200), but only at the expense of the number of switching paths through the unit.

The highest trunking efficiency can be obtained

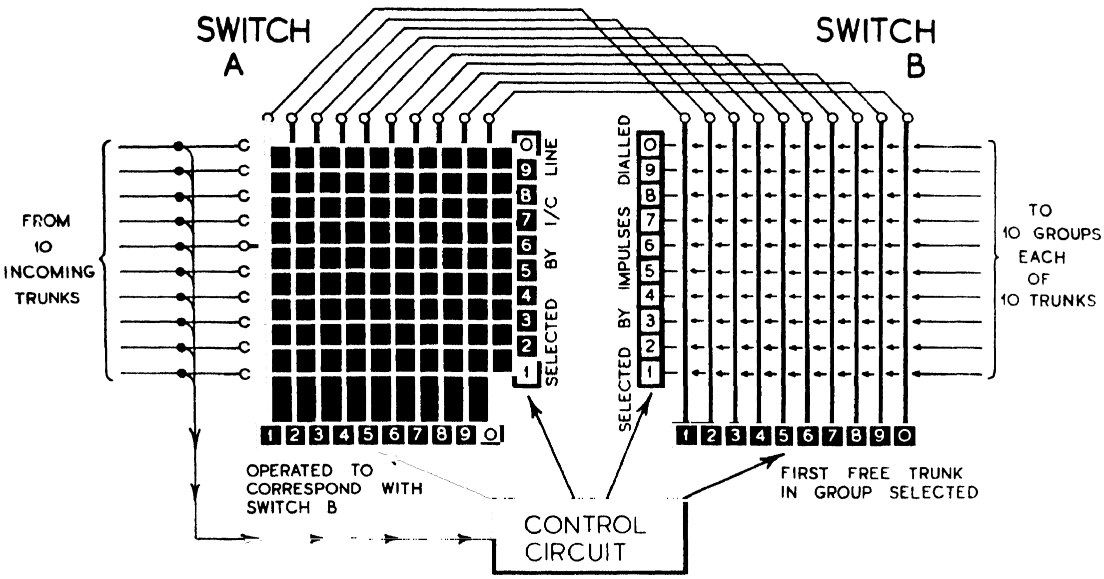


Fig. 634. Pair of Crossbar Selectors Used to Provide Access from Ten Incoming Trunks to Ten Outgoing Groups Each of Ten Trunks

when crossbar switches are arranged in pairs at each switching stage. Fig. 634 shows a typical example. In this case two crossbar switches (designated *A* and *B*) are arranged in tandem to provide access from 10 incoming trunks to any one of 10 outgoing groups each of 10 trunks. This pair of crossbar switches gives the same facilities as ten separate 100-point selectors of the Strowger type. If a call is routed on any one of the incoming trunks, the seizure of this trunk operates the appropriate select magnet of switch *A*, and takes up the control circuit associated with the pair of crossbar selectors. Signals are passed to the control circuit to determine which one of the 10 outgoing groups is required. (This may take the form of impulses from the subscriber's dial, impulses from a register, or marking conditions from a separate control circuit.) The control circuit energizes the select magnet of switch *B*, and then operates the hold magnet of the first free outgoing circuit in the selected group. The corresponding hold magnet of switch *A* is now operated, so that the incoming trunk is extended through switches *A* and *B* to the free trunk in the selected group of outlets. The use of two crossbar switches in this way provides facilities for 10 simultaneous calls, *provided that the number of calls to be set up at any particular time is limited to one*. Clearly, the trunking efficiency of a crossbar system is dependent upon the time taken to establish a connexion through a crossbar switching stage. In practice, it is usual to place a number of crossbar switches in a common group in order to provide a more even flow of traffic and to increase the availability.

Control of Crossbar Selector. In general, there are two methods of controlling the switching operations of a crossbar selector:

(*a*) Step-by-step switching, and

(*b*) Marker control of switching.

Each electromagnet of a crossbar selector is, in some respects, comparable with a normal telephone relay. It is possible to arrange the 10 selecting magnets of a crossbar selector as 10 relays in an impulse counting circuit. The circuit could be arranged so that the first impulse from the subscriber's dial operates selecting magnet No. 1, the second impulse operates the second selecting magnet, and so on. At the end of the impulse train, one particular selecting magnet, in accordance with the digit dialled, would be operated. If, at the end of this first train, the impulsing contact is switched to the hold magnets, the process of selection under the control of the dial could be repeated for the final digit. At the end of the second digit, a particular hold magnet would be operated, and this, in conjunction with the operated selecting magnet, would switch the call to the required outlet. Step-by-step control of switching is illustrated in Fig. 635 where it is assumed that the first digit is 3, thereby operating No. 3 selecting magnet. The operation of contact *E* at the end of the first train diverts the second impulse train to the hold magnets, and, at the end of the second train, the 6th hold magnet is energized to route the call to outlet 6 on the 3rd level. Thus, the switch operates substantially in the same way as a 100-outlet final selector of the Strowger type.

The crossbar switch can similarly be used as a 100-outlet group selector by arranging for the selecting magnets to be operated in accordance with the digit dialled, but with the hold magnets arranged as an automatic relay type hunting circuit (such as in Fig. 280). If desired, the same principle of step-by-step selection can be applied with automatic hunting on both the select and hold magnet chains, thereby giving the equivalent of a 100-point hunting mechanism.

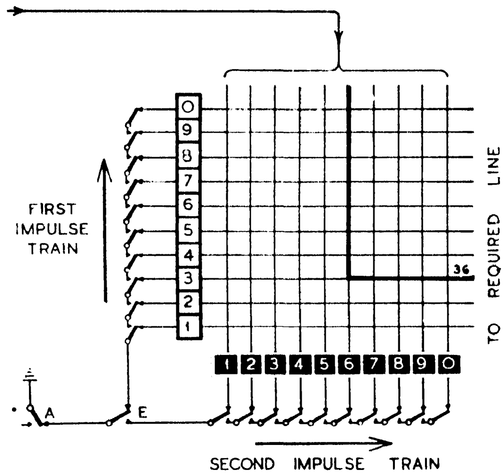


FIG. 635. STEP-BY-STEP CONTROL OF CROSSBAR SELECTOR

One obvious use of the crossbar selector is as a digit storage mechanism. The selecting magnets can be used as an impulse counting chain, and, if the hold magnets are operated in turn at the end of each train, the switch is capable of storing 10 or 20 digits (100-point or 200-point selector).

It has been seen in previous paragraphs that the trunking efficiency of the crossbar switch is largely influenced by the time necessary to set up a call through a switching stage. Whilst the step-by-step method of control has the great merit of simplicity, the setting up time is comparatively long. The marker system of control is better in this respect,

in that the control circuit (Fig. 636) predetermines the appropriate magnets which are to be operated, and the actual switching operation is merely the successive operation of the two magnets. With a marker scheme, the impulses from the subscriber

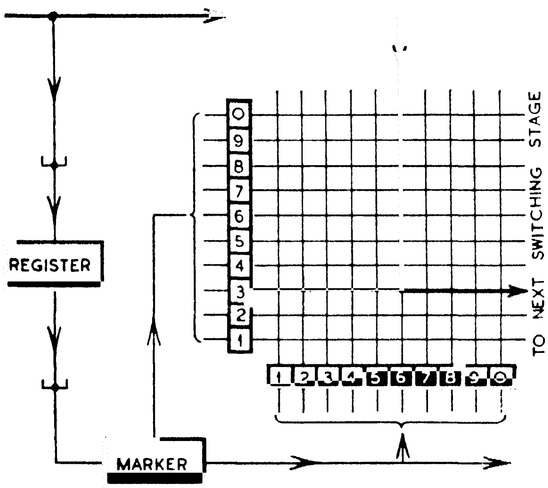


FIG. 636. MARKER CONTROL OF CROSSBAR SELECTOR

are received by a register which, in turn, passes the appropriate routing information to a marker. The marker operates, first the selecting magnet, and then the required holding magnet, to complete the switching operation. Separate markers may be provided for each crossbar switching stage or, as in the American system, one marker may complete the switching of the call through all the various selector stages.

THE AMERICAN CROSSBAR SYSTEM

The American Crossbar System was developed by the Bell Telephone Laboratories, and the first exchanges of this type were opened in the U.S.A. in 1938. The system was designed expressly to meet the complex switching problems of exchanges in large cities with the object of replacing the Panel system which was previously the most common method of automatic switching in areas of high telephone density. It follows that in the design of the Crossbar System particular regard had to be paid to the interworking of Crossbar exchanges with adjacent exchanges of the Panel and other types.

In the design of the American system efficiency in the trunking arrangements has been one of the prime considerations. The marker control method is employed throughout for the operation of the crossbar switches, whilst the control circuits are, wherever possible, concentrated into common equipment. It should be noted that the extremely short time necessary to effect selection with the crossbar switch makes the system particularly suitable for the concentration of the control equipment into a few common circuits which are used only during the setting up of a call, after which they are free to handle subsequent calls.

The Multi-contact Relay. The design of the American Crossbar System is such that it is frequently necessary to extend the control (or P) wire of a large number of circuits simultaneously to the common controlling and marking equipment. The ordinary type of telephone relay has a limited spring capacity, and it would be uneconomical to carry out these functions by the provision of banks of ordinary relays. A special multi-contact relay has therefore been designed for use with the Crossbar System. This relay is illustrated in Fig. 637. The relay is provided with 2 separate magnets, each of which controls one-half of the total number of spring sets. Thus, by operating the 2 magnets independently, the multi-contact relay can be used as 2 separate relays, but, if a large number of contact springs is required, it is necessary to operate both relays in parallel to actuate the full complement of springs. There are 4 sizes of multi-contact relay to provide

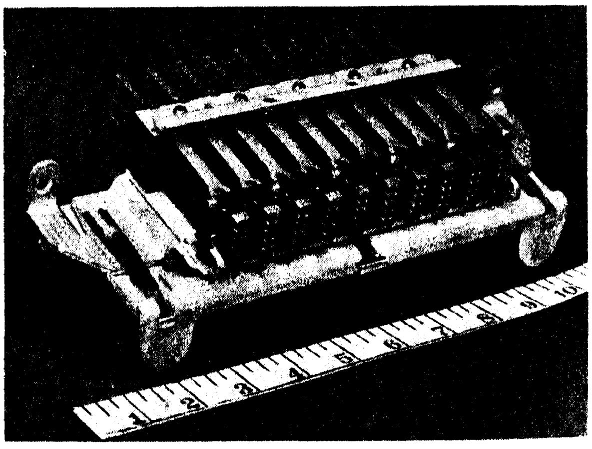


FIG. 637. MULTI-CONTACT RELAY

for 30, 40, 50 or 60 pairs of make contacts. The contact springs are provided with twin contacts of a type similar to those on the crossbar switches themselves. Similarly, the wiring tags of the contact springs are arranged so that it is possible to simplify the wiring by the use of bare wire straps.

Apart from the crossbar switch and the multi-contact relay, the Crossbar System is made up

almost entirely of relays of the ordinary telephone type. These relays are of standardized construction and bear a general similarity to the flat type of relay illustrated in Vol. I. There are 2 types of general purpose relay known as the U and Y types. The U type is the normal fast operating relay and has accommodation for a total of 24 springs. The Y type is similar but is provided with copper or aluminium sleeves to give slow operating and release characteristics.

Switching Principles. The Crossbar System, like all other systems of automatic switching, relies upon successive stages of selection to ensure economic use of the switch mechanisms. The principle adopted in the Crossbar System is to provide *primary* and *secondary* switching at each point of selection. Fig. 638 shows in schematic form the trunking arrangements between the subscribers' lines and the first selective switching point. The equipment racks are designed to accommodate 10 crossbar switches as a vertical tier. The subscribers' lines are connected in groups of 20 to the vertical paths of each crossbar switch. Thus each vertical tier of crossbar switches will accommodate a total of $20 \times 10 = 200$ subscribers' lines. Several such tiers may be connected together (i.e. with the horizontal paths multipled) to form a *primary group*. The number of lines in a primary group is determined by the calling rate of the subscribers, and in practice may range from 150 to 700, i.e. the number of primary switch bays may range from 1 to 4, depending upon the calling rate.

The horizontal paths (100 in number) of the primary switches are trunked to the horizontal paths of 10 secondary switches, which are arranged as a single vertical tier. The trunking arrangements are such that the 10 links from any one primary crossbar switch are spread over all the 10 secondary switches of the group, so that there is one trunk from each primary switch to each secondary switch. In the Crossbar System the *line-link frame*, consisting of primary and secondary switches as described above, is utilized for both incoming and outgoing calls to subscribers in the group. In this respect the frame fulfils the functions of a line-finder and of a final selector in the Strowger System. In order to provide for both incoming and outgoing traffic, the vertical paths of the secondary switches are arranged as 2 equal groups, each consisting of 100 trunks—10 from each secondary switch. The system of control is such that, when a subscriber wishes to make a call, the appropriate position on the primary switch, a free link between the primary and secondary switches and a free outgoing trunk are all marked before switching takes place. It is clear, therefore, that a very high standard of availability is obtained by the primary and secondary trunking arrangements.

Whilst the primary and secondary switching arrangement illustrated in Fig. 638 is satisfactory as a means of associating a calling line with any one of 100 trunks to the first selective switching

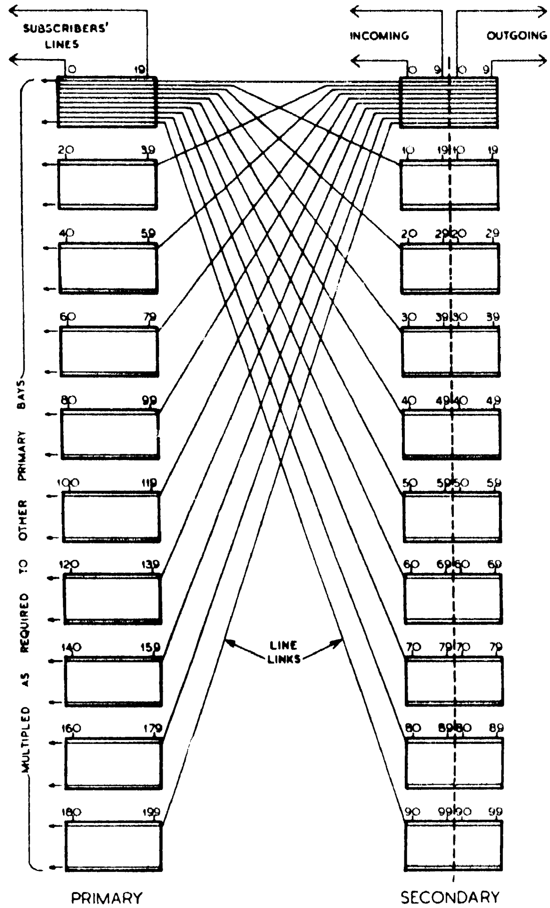


FIG. 638. METHOD OF ASSOCIATING SUBSCRIBERS' LINES WITH 1ST SELECTOR STAGE

stage, the arrangement would not be very satisfactory for use in circumstances where the outgoing trunks are required to give access to a large number of separate groups. For example, a single stage of primary and secondary working would not be very satisfactory as a means of selecting a free outgoing junction in any one of, say, 50 possible junction routes. It would, in fact, give access only to an average of 2 junctions per group. It is therefore necessary to adopt two or more stages of primary and secondary selection in tandem to give the

required degree of availability. The trunking arrangements of the intermediate switching points in the Crossbar System are therefore somewhat complex, but the inherent flexibility of the crossbar switch makes possible a variety of primary-secondary switching arrangements by the use of horizontal and vertical paths as required. A typical trunking arrangement is given in outline later.

Senders and Markers. A noticeable characteristic of the American Crossbar System is the complete elimination of controlling relays from the Crossbar switch circuits themselves. The relays required for transmission, ringing, holding, etc., are concentrated in 2 relay sets. The first (known as the *district junctor* relay group) provides the transmitter feeding current to the calling subscriber, contains the necessary relays for supervisory purposes and is responsible for the energization of the holding magnets on the switches used for the outgoing portion of a call. The second relay set (known as the *incoming trunk* circuit) contains the necessary relays for providing automatic ringing, supplies speaking battery to the called subscriber and is responsible for the energization of the holding magnets on the selectors used for the incoming portion of a call.

Apart from these 2 relay groups, most of the controlling relays are concentrated in common control circuits known as senders and markers. Two separate senders (known as the *subscriber's sender* and the *terminating sender*) together with two markers (known as the *originating* and the *terminating markers*) are required for the establishment of a call. The subscriber's sender receives the impulses from the calling subscriber's dial and, when the routing is determined, passes forward the appropriate directions to the originating marker. The originating marker is, in turn, responsible for choosing a disengaged junction to the required exchange and for selecting suitable disengaged links through the crossbar switches. When free equipment at the called exchange has been seized, the subscriber's sender passes forward details of the required subscriber's number to a terminating sender at the called exchange. The terminating sender in turn determines the location of the required line on the crossbar switches and passes forward the routing information to the terminating marker. Finally, the terminating marker is responsible for testing the called line and for establishing the call through suitable free links in the crossbar chain.

The subscriber's sender has also a number of other functions, such as the classification of calls either as ordinary or as coin-box. In addition, the sender determines the type of exchange to which the call must be routed and is responsible for transmitting to that exchange the appropriate signals. The terminating sender is not required to effect such differentiation and is correspondingly simpler in design.

The markers are the most important control circuits of the Crossbar System. They are composed of ordinary telephone type and multi-contact relays. The operating time of the markers is extremely short—actually a marker is engaged for only 0·5 to 0·6 of a second on each call. Hence, only 3 or 4 markers of each type are required in an exchange of average size. The originating markers determine the proper route to the called exchange and have access to all outgoing junction circuits in addition to the various crossbar switch frames that may be used to establish a connexion. The originating marker tests the outgoing junction group to find a free junction to the called exchange and also tests and selects an idle channel through the crossbar switches. Finally, it operates the appropriate selecting and holding magnets to establish the connexions from the subscriber's line to the junction.

The terminating markers perform similar functions in the terminating exchange. They have access to all subscribers' lines terminating in the exchange and to all crossbar frames necessary to establish a connexion to those lines. They also test the called line for the engaged condition and finally operate the appropriate magnets of the crossbar switches to establish a connexion to the called line.

In addition to the senders and markers, there are certain common control circuits which control the selection of the senders and also the switching of a called subscriber's line to the common equipment.

Trunking Scheme—Originating Exchange. A simplified trunking diagram of a crossbar exchange is given in Figs. 639 and 640. The arrangements shown are suitable for a large city exchange where a high percentage of the originated traffic is routed over outgoing junctions to other nearby exchanges. The process of establishing a call from one crossbar subscriber to another crossbar subscriber may be considered as six distinct stages:

(*a*) The calling subscriber is connected to a subscriber's sender for the purpose of recording the number dialled.

(*b*) When the full routing code has been received, the subscriber's sender is connected to an originating marker.

(*c*) The marker selects the outgoing junction to be used and suitable free paths through the crossbar switches to connect the calling line with the selected junction.

(*d*) The junction circuit is connected to a terminating sender at the incoming exchange to receive (from the originating exchange) details of the number required.

(*e*) When the terminating sender has received details of the called subscriber's number, it is connected to a terminating marker.

(*f*) The terminating marker selects the required subscriber's line and establishes the connexion with the incoming junction through suitable disengaged paths to the crossbar switches.

Each subscriber's line is terminated on the vertical path of a primary crossbar switch as already illustrated in Fig. 638. When the subscriber's receiver is lifted, the operation of the line relay brings into use the line-link control circuit which is common to a complete frame of primary and secondary switches. The control circuit determines the primary crossbar switch in which the line is located and the particular vertical unit of the switch on which the line is terminated. The line-link control circuit now simultaneously selects an idle link between the selected primary switch and one of the secondary switches which has at least one free outlet.

The sender-link control circuit is now seized and selects a disengaged relay group (known as a district junctor) from the group of such circuits marked by the line-link control circuit. The district junctors are terminated on primary crossbar switches on the sender-link frame, and there are 10 links from each primary switch to the vertical paths of a common group of secondary switches. The horizontal paths of these secondary switches are, in turn, connected to subscribers' senders. The sender-link control circuit now tests the links between the primary and secondary switches and the outlets to the senders to find an idle sender-link which has access to a group of senders in which there are one or more idle circuits. When this selection has been made, a particular idle sender in the group is selected.

The line-link and the sender-link control circuits working in co-operation operate first the selecting magnets and then the holding magnets associated with the paths selected through the crossbar switches both on the line-link and on the sender-link frames. The calling subscriber is now extended to an idle subscriber's sender. The two control circuits are then released and are available for use on other calls, the connexions through the switches being held under the control of the relays in the subscriber's sender. Before the control circuits release, however, they transmit certain information to the sender. In the first place, they indicate whether the call originates from an ordinary or a coin-box line. Secondly, the sender-link control circuit signals to the sender the number of the district-link switch frame on which the selected district junctor appears. The sender-link control circuit also tests the paths from the calling subscriber's line circuit to the sender before releasing from the connexion. This automatic testing of the speech paths before a call is established is a feature of the Crossbar System. If on this test a fault is revealed, the control circuits make further trials to establish the connexion over different paths and give an alarm to indicate the fault conditions encountered.

The above operations are completed in a fraction of a second, and the seizure of a sender transmits dial tone to the calling party. The impulse trains from the calling subscriber's dial are received by the sender which records the digits on a crossbar selector. When the sender has registered the complete routing code (generally the first 3 digits of the number dialled), the sender connects with an idle originating marker via a multi-contact relay in the marker-connector circuit. The sender now passes forward to the marker details of the called exchange and the identification of the district-link frame position of the calling line. One route relay for each outgoing junction group is provided in the marker circuit, and the operation of one particular route relay from signals transmitted by the sender provides all the information required by the marker to select the required paths through the crossbar switches. The connexions of the route relay also determine the type of the called exchange, e.g. crossbar, panel, manual, etc., and an appropriate signal is returned to the subscriber's sender in order that the latter can transmit the correct signals over the junction at a later stage. It is interesting to note in passing that the connexions of the route relay contacts are so arranged that routing changes, and changes necessitated by the conversion of other exchanges in the area, can be readily made.

When the route relay has been operated, the marker proceeds with the establishment of the call by the operation of district and office connectors. The operation of the office connector extends to the marker the test wires of the desired outgoing junction group and the links between the primary and secondary switches of the office-link frame. The marker has now full control of the outgoing junction group and of the switches on the office-link frame, and any other markers which desire connexion to the same frame must await the release of the first marker.

The marker next tests the outgoing junctions to the required exchange and selects a disengaged

circuit. The circuit arrangements are such that the outgoing junctions can be divided over more than one office-link frame, and in these circumstances the marker may connect to several office-link frames in an endeavour to find an idle circuit.

Coincident with the above operations, the marker operates a district connector which links the marker circuit with the paths of the district-outgoing junction circuit. The marker tests the possible channels in groups, and selects an idle one. It then operates the selector magnets to switch through the call.

When the marker has completed this operation, it checks the connexion to ensure that it has been properly established, and then releases to become available for use on other calls. It should be noted that the marker performs all these functions in a

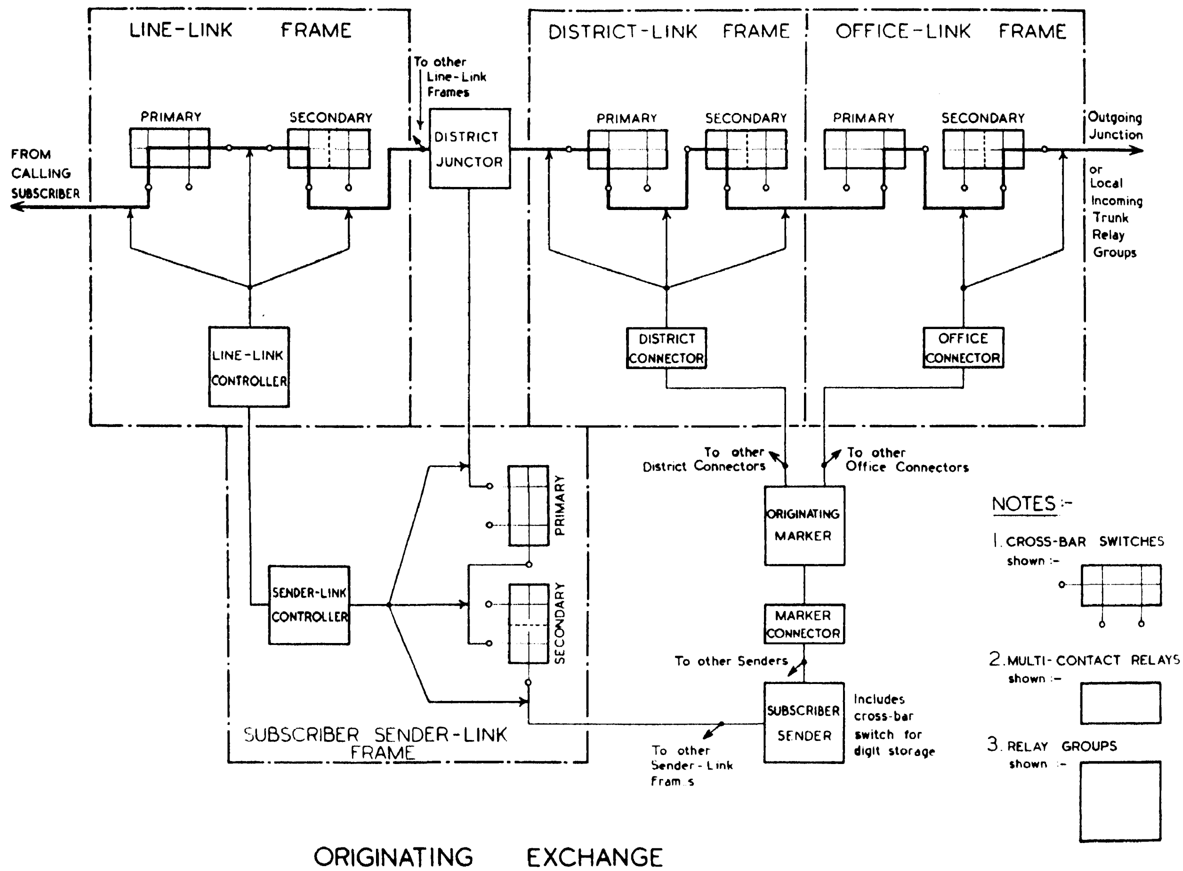


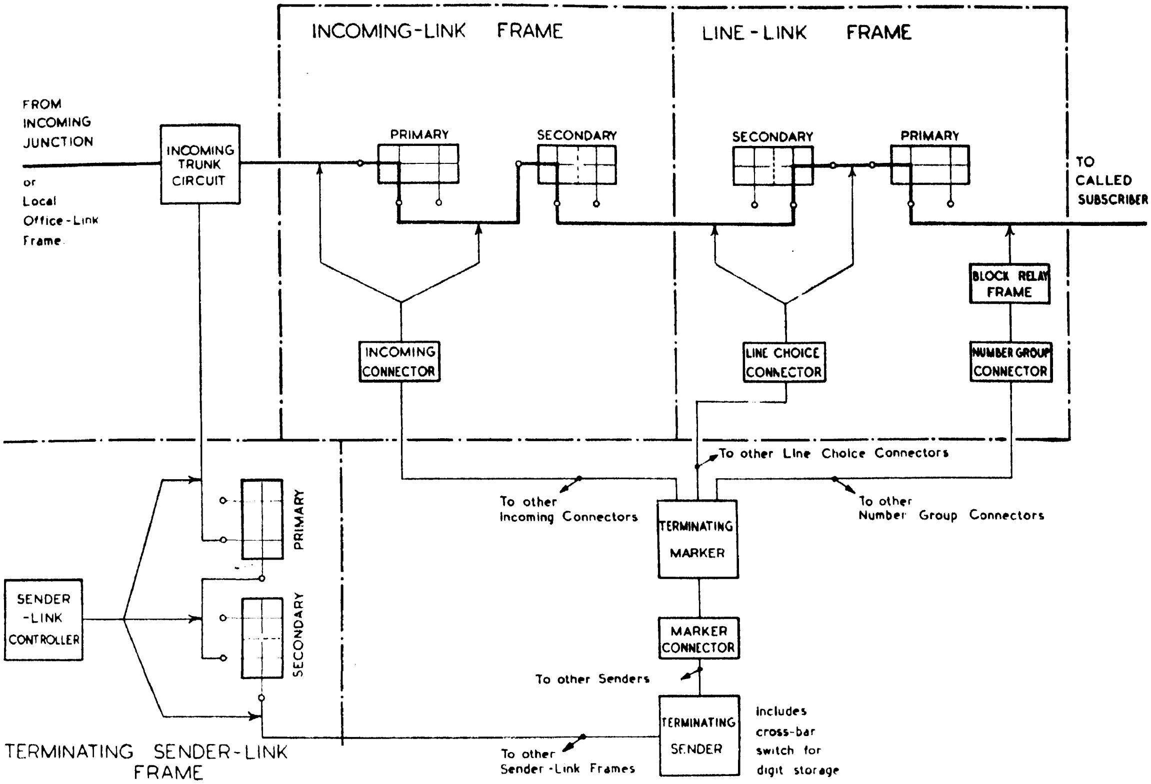
Fig. 639. Trunking Scheme—Originating Exchange

link frame associated with the district junctor circuit already selected. (Information to identify this frame is passed from the sender to the marker.) Only one marker can be connected to a particular district-link frame at any one time. The marker first selects an idle trunk circuit (which appears on a horizontal circuit path of one of the secondary switches of the office-link frame) and then proceeds with the selection of an idle path through the switches of the district- and office-link frames. It is clear that there is a number of possible paths between a selected district junctor and the chosen very short time—usually of the order of 0·5 sec. Facilities are provided so that, if it is impossible to establish a call over the primary route, the marker makes a second trial to establish the connexion over an alternative route.

Trunking Scheme—Terminating Exchange. The incoming junctions at a crossbar exchange are terminated on incoming trunk relay groups which contain the called subscriber's transmission bridge, the supervisory relays, holding relays, etc. The seizure of an incoming trunk circuit operates the sender-link control circuit associated with the

terminating sender-link frame on which the incoming junction appears (Fig. 640). As in the case of the subscriber's sender-link frame, the incoming circuits are connected to vertical paths of primary crossbar switches, the horizontal links of which are connected to vertical paths of secondary switches. The horizontal paths of the secondary switches are in turn connected to terminating switches at the incoming exchange are held under the control of the terminating sender.

The terminating sender is now connected directly with the subscriber's sender at the originating exchange. The subscriber's sender transfers details of the called number over the junction to the equipment in the terminating sender and, when this operation is completed, the subscriber's



TERMINATING EXCHANGE

Fig. 640. Trunking Scheme—Terminating Exchange

senders. The sender-link control circuit locates the incoming junction circuit and selects an idle link between the primary switch and a secondary switch on which there is an idle terminating sender. The control circuit now selects one of the disengaged terminating senders and then operates the selecting and holding magnets to switch through the call from the incoming trunk circuit to the selected sender. The control circuit also signals to the sender the number of the incoming-link frame on which the junction appears. After testing the paths through the sender-link crossbar switches, the control circuit now releases. The crossbar sender releases and the equipment at the originating exchange is placed under the control of the district junctor circuit. As in the Director System, the subscriber's sender is arranged so that it is not necessary to await receipt of the complete called number before details of the earlier digits are transmitted.

When the terminating sender has received full details of the number of the called line, it connects itself to a disengaged terminating marker via the multi-contact relays of a marker-connector circuit. As at the originating exchange, the terminating marker is responsible for selecting suitable paths

through the equipment and for the necessary switching operations. When a terminating marker has been seized, the sender transfers to the marker details of the called number and of the incoming-link frame location of the junction.

The terminating marker now connects itself to a particular number group connector which gives access to the called subscriber's line. By this means the marker obtains access to the control (or P) wire of the required line and tests for the engaged condition. The marker also ascertains details of the appropriate line-link frame and obtains the number of the primary line-link selector on which the called line is terminated. In addition, the marker obtains from the electrical conditions on the test terminals the type of ringing to be applied to the called line. This is, of course, necessary when party lines are connected to the system.

The marker also determines if the required line is one of a P.B.X. group and, if so, tests all the lines in the group before busy tone is returned to the caller. It is interesting to note that particular attention has been paid to the question of P.B.X. facilities in the Crossbar System. The circuits are arranged so that a very high speed of search over the lines of a P.B.X. group is obtained—(as many as 20 lines can be tested simultaneously). It is

FIG. 641. GENERAL VIEW OF CROSSBAR EXCHANGE

also arranged that the lines of a P.B.X. may be given any number either within or without the exchange numbering scheme. This feature reduces number changes necessitated by the growth in the size of P.B.X. groups, and by the use of numbers outside the normal range it conserves the normal subscribers' numbers.

If the number dialled is that of a spare line, the marker automatically routes the call to the operator. If the called line is idle (or when a free line in a P.B.X. group has been found) the operation of the line-link connector extends the marker circuit to the link between the primary and secondary switches of the line-link frame and to the appropriate group of trunks between the incoming and line-link frames. The marker now selects an idle channel through the incoming-link and the line-link frames, and finally operates the appropriate selecting and holding magnets of the crossbar switches to establish the connexion from the incoming trunk circuit to the called subscriber's line. The marker signals to the incoming trunk circuit details of the appropriate ringing conditions, and ringing tone is returned to the caller.

If the terminating marker encounters busy conditions on the called line, it signals to the incoming trunk circuit to transmit busy tone to the calling subscriber. The terminating marker is now released from the connexion.

The circuit paths of an established connexion are indicated by the heavy lines of Figs. 639 and 640. The connexion is established through a total of 10 crossbar switches, whilst the control is vested in 2 relay groups (the district junctor and the incoming trunk circuit). Although Figs. 639 and 640 assume that the call is routed from one crossbar exchange over a junction to another exchange of the same type, the switching operations for a local call on the same exchange are precisely the same, i.e. the appropriate incoming trunk circuits are terminated direct on the horizontal paths of the secondary switches in the office-link frame.

Fig. 641 gives a general view of a typical apparatus aisle in a large crossbar exchange.

THE SWEDISH CROSSBAR SYSTEM

Outside the larger cities and towns of Sweden the population consists mainly of small isolated communities spread over a very great area of territory. Of the total number of some 6000 exchanges, nearly 5000 of them have less than 100 lines, and quite a high percentage of the latter have less than 20 lines. The automatization of the telephone service in Sweden began (as in most other countries) with the conversion of the exchanges in the main cities and the more important towns. As the conversion proceeded, it became necessary to design equipment which would be suitable for very small exchanges in isolated localities. The prime requirement of such exchanges must be reliability, simplicity of operation, and low maintenance costs. The equipment must, moreover, be capable of working satisfactorily under the most adverse climatic conditions (the northernmost territory of Sweden is within the Arctic Circle).

The Swedish Telephone Administration designed, in 1933, an experimental rural automatic system, incorporating the crossbar switch. This system was placed on trial at various centres and gave very promising results. In 1938 a decision was taken to standardize a step-by-step crossbar system for all exchanges under 2000 lines capacity. Exchanges with a greater capacity would continue to use the Ericsson 500-point selector scheme, which offered some economic advantages over the step-by-step crossbar system for the larger units. The standardization of the crossbar system was completed in 1941 and is known as the "Standard 41 Crossbar System." The No. 41 System employs unit construction for the smaller exchanges, and it is possible to install units to provide for a maximum of 40, 60, or 100 lines. Exchanges of between 100 and 2000 lines are individually designed.

Numbering Scheme. All telephone subscribers throughout Sweden will ultimately be allocated an 8-figure national number. This number may be considered as comprising two parts, i.e. the area code number, and the local exchange number. In general, the area code number consists of the first three digits, and is not included in the directory number of the subscriber. The directory number contains the remaining five digits, the first two of which usually represent the code of the particular exchange within the area. For calls to exchanges within the area, the subscriber merely dials the directory number of the wanted subscriber. For calls to adjacent areas, the required directory number must be prefixed with the code number of the required area, which is shown at the top of each page of the directory.

The national numbering scheme in Sweden has been designed on the basis that translation of the routing digits will be provided on all except local calls. This requires that a register or other similar device should be available to any subscriber when a call is initiated. Unfortunately, registers and translator devices are comparatively complex, and would materially complicate the equipment at the small rural exchanges. The difficulty has been overcome by concentrating the registers in the

more important junction centres and group centre exchanges.

Trunking Scheme of No. 41 Type Terminal Exchange. Fig. 642 shows a typical trunking diagram of a 100-line "terminal" exchange. The subscribers' lines are connected to the horizontal circuits of a 100-point crossbar switch, the ten bridges of which are commoned together to give access to a discriminating selector. The discriminating selector is in two parts, i.e. the vertical bridges are arranged as pairs, each pair being directly connected to a linefinder. In essence, the discriminating selector functions as two 10-point

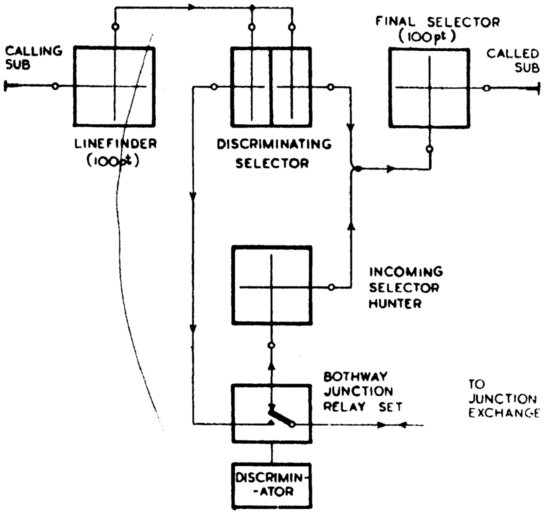


Fig. 642. Trunking Scheme, No. 41 Type Terminal Exchange

uniselectors. The first bridge gives access to the outgoing junctions, whilst the second portion switches to the final selector stage. It is clear that the discriminating selector can carry two or more calls consecutively, but the use of a single common control relay group prevents more than one call being set up at the same time. When the subscriber lifts his receiver, his line is extended via the linefinder and the junction portion of the discriminating selector to a disengaged junction relay set. Dial tone is received when a register at the distant "junction" exchange is seized (see Fig. 643). The subscriber can now dial the required number. The impulse trains are passed to the register at the junction exchange and, at the same time, are counted on a local discriminator associated with the outgoing junction equipment at the terminal exchange. If the subscriber dials the code of his own exchange, the discriminator returns a signal to the discriminating selector, which then hunts for a free final selector. The outgoing relay set and the register at the distant exchange are now released. The final selector requires only two digits, and the circuit arrangements are such that the third digit of a local call is absorbed in the junction relay set. (This feature allows time for the distributor to locate a free final selector.)

Incoming calls are routed through the junction relay set to an incoming selector hunter, which gives direct access to the final selectors. The selector hunter therefore functions in a manner somewhat similar to the discriminating selector on local calls.

An interesting feature of the exchange is the provision of a "blind" junction relay set, i.e. a relay set without a junction. This relay set ensures that local traffic is not blocked when all outgoing junctions are busy. Local dial tone is provided from this circuit and, if the call is for a local number, switching to a final selector takes place as described above. Demands for outgoing junction calls receive busy tone.

It should be noted that the final selector is operated on the step-by-step principle, the first train of impulses operating the selected magnets, and the second train of impulses operating the appropriate bridge magnet.

Fig. 643 shows front and rear views of a typical 40-line terminal exchange of the crossbar type. This exchange is equipped with 5 linefinders, 5 discriminating selectors, 5 final selectors and a maximum of 4 bothway junction relay sets and selector hunters. The numbering range is 10–49.

Trunking Arrangements of Junction Exchange. The trunking arrangements of a junction exchange are illustrated in Fig. 644. As before, the calling subscribers' lines are terminated on 100-point linefinders, which in turn are directly connected to 10-point preselectors. This arrangement gives the required high degree of concentration and mixing of the traffic. The preselectors give access to 1st group selectors which (like the discriminating selectors of the terminal exchange) are divided into two parts. One portion gives access to 2nd group selectors, whilst the outlets of the other part are connected (via relay sets) to the outgoing junction routes.

When the calling subscriber lifts his receiver, he is connected (via the linefinder, preselector, and register hunter) to a free register. The register returns dialling tone to the calling party and receives the impulse trains from the subscriber. The second exchange code digit is also received on the 1st group selector. If a local call is required, the register discriminates and releases, and from this point onwards the 2nd group and final selectors

difficult to forecast the probable line of development, especially in view of the very rapid progress which is being made in the design of electronic circuits for a very wide variety of purposes. A major problem in the design of an electronic switching system will undoubtedly be the necessity for interworking with existing automatic systems of the electromechanical switching type.

It is interesting to consider the possible reactions of an electronic switching scheme upon other aspects of telephony. For example, the introduction of an electronic switching scheme could provide facilities for the amplification of speech on local connexions, and hence it might be possible to abandon the carbon transmitter in favour of, say, a moving-coil unit which would give a much higher degree of intelligibility and naturalness to telephonic speech. (The signal-to-noise ratio on the line would be an important factor in this connexion.) Electronic switching might also open the way for the use of carrier systems between the subscriber and his local exchange, or between successive switching stages of the exchange equipment.

EXERCISES XXI

1. Explain the principal features of the trunking arrangements in the Relay Automatic System and, with the aid of a block schematic diagram, describe the operations involved when one subscriber calls another. (*C. & G. Telephone Exchange Systems III*, 1948.)

2. Explain how it is possible, in a Relay switching system, to economize in the number of relays required by providing "limited availability" conditions between the subscribers' lines and the common link circuits. What factors determine the savings obtainable in this way?

3. Give a diagram of a suitable circuit element which provides for the counting of two trains of impulses by means of a group of relays. Show by means of a chart how these relays are operated in response to different incoming digits.

4. Describe, with the help of suitable sketches, the principle of operation of the Crossbar selector. In what circumstances is it possible to route two or more consecutive calls through the same switch?

5. Show how it is possible to use a 200-point Crossbar selector

(*a*) as a 200-point step-by-step selector;

(*b*) as a means of connecting any one of 10 trunks to a free outlet in a group of 20 outgoing trunks by means of marker control principles.

6. Give a simple trunking diagram to show how, by means of primary and secondary groupings of Crossbar switches, a group of 200 subscribers' lines can be served by a common group of 20 1st selectors.

7. Give an outline of the trunking arrangements at a large American Crossbar exchange. Explain the functions of the originating marker.

8. Describe the fundamental differences between the Crossbar System developed in Sweden and that developed by the American authorities.

9. Give a simple trunking diagram and describe the main circuit operations of a small rural Crossbar exchange in Sweden.

10. Discuss the possible ways in which electronic devices might be used in the design of an automatic switching system.

CHAPTER XXII

LONG-DISTANCE DIALLING

In the early days of automatic telephony, dialling was limited to the local automatic area, all junction and trunk circuits being worked on a simple manual signalling basis. As the system developed, improvements were made in the design of impulsing circuits so that it became possible to examine the prospects of providing dialling facilities over greater distances. The rapid growth of the trunk and toll traffic in recent years has still further emphasized the economic and service advantages which can be obtained by an extensive system of dialling on a national or even an international basis.

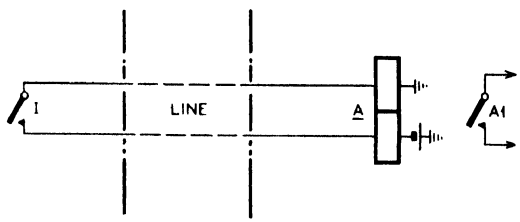


Fig. 648. Principle of Loop-disconnect Impulsing

During the past ten or fifteen years very considerable strides have been made in the technique of long-distance dialling. Some of these methods utilize direct current signals, and hence are applicable to the shorter trunk and toll circuits where physical conductors are provided per circuit. It is now standard practice to route the longer trunk circuits over carrier or coaxial routes where one physical conductor may serve a large number of individual traffic circuits. For such routes there is no alternative to the use of voice-frequency currents for dialling.

The early part of this chapter deals with some of the problems of long-distance impulsing by means of direct currents, whilst the latter part of the chapter is devoted to the principles and practice of voice-frequency dialling.

Loop-disconnect Impulsing. The method of impulsing between a subscriber and his local exchange is largely determined by the necessity for a simple impulse sending circuit at the subscriber's instrument, and by the need for co-ordinating the impulsing circuit with the normal central battery transmission system. The simplest and most obvious method is to arrange for the impulse sending device to break the d.c. loop current during each impulse, with the impulse accepting relay also serving as the transmission bridge impedance element (Fig. 648).

Any method of direct current impulsing can be used between successive switching stages in the exchange and over the junctions to adjacent exchanges. It is usual (in the British system) to retain loop-disconnect impulsing between switching stages to avoid the circuit complications which are introduced in changing from one type of impulsing (in the subscriber's loop) to another type of impulsing through the exchange and over the junctions.

We have seen in Chapters V and VI that impulse distortion can occur at each repetition point due to various factors, such as the electrical characteristics of the line, the inductance and mechanical design of the impulse accepting relay, and so on. If loop-disconnect impulsing is used on long junction circuits, the line capacitance produces a decay wavefront (when the impulsing contacts open) which is considerably more gradual than the arrival wavefront when the contacts remake. This is, of course, due to the line charging current which passes through the coils of the impulse accepting relay during the open-circuit period (i.e. during the break impulse). Fig. 649 shows a typical

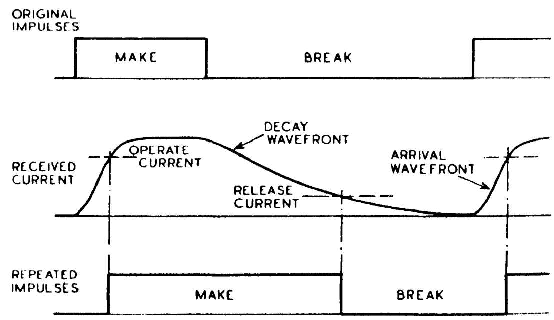


Fig. 649. Typical Waveform on Very Long Reactive Lines (Loop-disconnect Impulsing)

waveform of an impulse received over a long reactive line. The current decay curve is so gradual that an appreciable time elapses before the current falls to the release value of the relay, with the result that the make period of the impulse is materially lengthened.

It is interesting to note that the distortion produced by the capacitance of a long underground

circuit (i.e. a reduction in the break ratio) is similar in effect to the distortion produced on a *short* leaky line. In the latter case, of course, there is an appreciable time before the current in the relay falls to the release value due to the combined effects of the leakage current and the high value of loop current. The distortion is opposite to that produced on a long non-reactive line where the ohmic resistance of the circuit introduces a time interval before the current in the relay can reach its operate value. The use of the terms "long line" or "short line" distortion can be somewhat misleading. On long circuits the line capacitance tends to neutralize the type of distortion produced by the high ohmic resistance of the circuit. If the capacitance is high, then distortion in the form of a decrease in the break ratio will occur but if, on the other hand, the line is substantially non-reactive, or has little capacitance, increased break distortion will result.

From an impulsing point of view, it is generally preferable to consider the *time constant* of the line rather than the ohmic resistance. (The time constant is given by the product of CRL^2, where C and R are the capacitance and resistance per loop mile, and L is the length of the line in miles.)

Impulsing over Amplified Lines. The distortion due to wire-to-wire capacitance is greatly increased on amplified circuits. Most junction and trunk circuits of more than 15 miles in length are provided with amplifiers to meet the speech transmission requirements. It is usual to work amplified circuits on a 4-wire basis, i.e. one pair of wires is used for the transmission of speech in one direction, whilst a second pair of wires is utilized for the return path. The signalling circuit is maintained by connecting together the centre points of the transformers on each side of every amplifier. The signalling currents are in fact transmitted over the phantom of the 4-wire circuit. Fig. 650 shows the normal signalling arrangements on a 4-wire amplified circuit. At each terminal the 4-wire to 2-wire conversion is made by the use of hybrid transformers as shown. The "go" and "return" d.c. signalling circuits are separated by capacitor C (usually 1 μF) in each termination. The wire-to-wire capacitance of the 4-wire phantom circuit is materially greater than that of a 2-wire circuit. This, together with the shunt capacitors (C) in the 4 to 2-wire terminations, produces a decay wavefront which is very gradual. The steepness of both the arrival and decay wavefronts is further reduced by the presence of the series inductance of the terminating transformers.

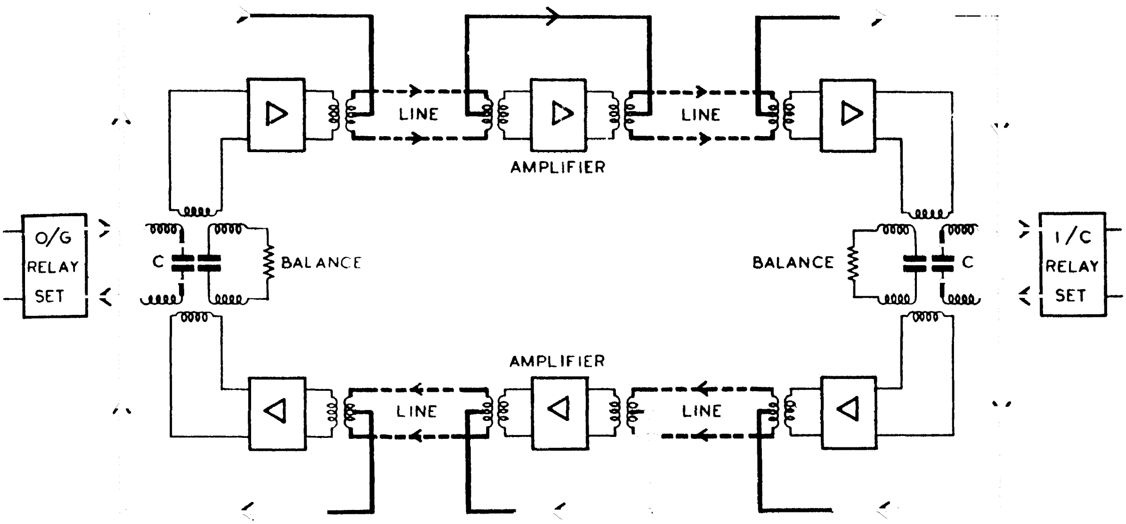


Fig. 650. Signalling Path on 4-wire Amplified Circuit

There is considerable difficulty in adopting any form of loop impulsing on 2-wire amplified circuits, owing to the difficulty of obtaining a satisfactory by-pass signalling circuit across the 2-wire amplifiers. The direct currents in the line transformers also tend to introduce instability.

Generally speaking, loop-disconnect impulsing can be used on underground lines up to about 1500 Ω resistance (assuming a 50 V signalling battery). The loop dialling limit for amplified lines is somewhat less—the most severe condition occurring when two or more successive links in a

tandem connexion are all routed over 4-wire amplified circuits.

The limiting condition in all cases occurs when the decay wavefront is so gradual that the flux does not completely die away before the commencement of the next make period. Unless the decay current wave attains the steady (zero) state before the next arrival wavefront begins, mutual interference occurs which is cumulative on successive impulses of a train. The impulsing limits of any particular circuit can be increased by a reduction of the impulse frequency. For example, a 4-wire circuit routed through a 20 lb star-quad cable can be operated successfully up to about 20 miles if the impulsing speed does not exceed, say, 13 I.P.S. If, however, the impulse frequency is restricted to a maximum of 12 I.P.S., then it may be possible to dial satisfactorily over 40 miles of the same cable.

Battery Dialling. The principle of battery dialling has already been considered in Chapter

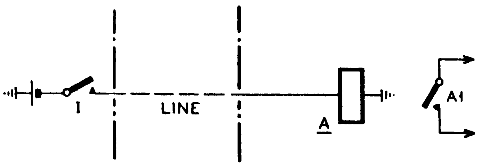


FIG. 651. PRINCIPLE OF BATTERY DIALLING

XVII. In this scheme the impulsing is confined to one wire of the junction, with the return circuit via the earth connexions at each end (Fig. 651). The lower ohmic resistance of the signalling circuit makes it possible to dial over circuits of greater length, but unfortunately the single-wire signalling feature introduces a number of other difficulties.

In the first place, battery dialling is subject to interference due to differences in the earth potential at the two ends of the circuit. In addition, the system is liable to produce interference in the cable pairs due to the unbalanced single-wire impulsing condition. This factor may not be serious on unamplified 2-wire circuits, but tends to become appreciable on 4-wire amplified circuits due to the fact that the phantoms of 4-wire star-quad circuits are not usually balanced against cross-talk.

There is a further difficulty due to the design of some types of amplifier. These amplifiers are provided with a common grid bias resistor, and the unbalanced current surges in the windings of the hybrid transformer produce a voltage surge which is impressed on the common bias resistor. This interference is communicated to all the other amplifiers served by the same resistor. Interference from this cause can be reduced by the provision of effective decoupling capacitors in the grid bias circuit.

With a 50 V battery, it is possible to utilize battery dialling on non-reactive lines up to about 2500 Ω, but, for the various reasons given above, the limit is reduced to some 600 Ω on 4-wire amplified circuits. Generally speaking it is not desirable to use battery dialling over amplified lines. (It should be noted that the time constant of the impulsing path is not materially reduced by adopting battery dialling. Although the resistance (R) is halved, the capacitance (C) is approximately doubled.)

Impulse Regenerators and Correctors. The dialling limits on junction circuits can, of course, be increased by the use of impulse correction devices or by regeneration of the impulse trains at suitable points. These methods are quite suitable where calls are to be established over comparatively short junction routes in tandem, but are not practicable (for economic and service reasons) on the longer trunk circuits. A normal underground trunk circuit would require regenerators at intervals of, say, 20 miles, and the cost of this equipment (and the necessary apparatus rooms) becomes prohibitive on the long trunk lines. Moreover, the fault liability of the signalling circuit increases rapidly as the number of repetitions is increased. Apart from these factors, the time delay introduced by impulse storage at the repetition points becomes intolerable on a long-distance circuit. Impulse correction devices are less costly than impulse regenerators, but they have their own inherent disabilities which have already been described in Chapter VI.

Analysis of Square-topped D.C. Impulse Signal. Examination of impulse distortion problems by considering the effects of charging currents resulting from the line capacitance, etc., is reasonably satisfactory when dealing with local networks and the shorter junction circuits. Such a simple conception does not, however, provide a satisfactory method of visualizing the transmission of a direct current impulse over a long trunk circuit. It is preferable in such circumstances to treat the direct current impulse as a series of alternating components of the correct amplitude, frequencies and phase relationship.

Each train of impulses can be considered as a square-topped alternating wave of a definite frequency (nominally 10 c/s). Each individual current impulse represents one half-cycle of this fundamental impulsing wave. It is well known that an alternating voltage with a square-topped waveform can be resolved into a fundamental

sinusoidal wave plus an infinite series of odd-order harmonics. The analysis can be expressed mathematically:

$$e = E \sin \omega t + \frac{E}{3} \sin 3\omega t + \frac{E}{5} \sin 5\omega t \ldots$$

etc. to infinity,

where e = instantaneous voltage,
E = maximum voltage,
ω = angular frequency (radians per sec)
$= 2\pi f$,
where f = frequency in c/s,
t = time in sec.

Fig. 652 shows the effect of adding together the instantaneous voltages of four sinusoidal waves, i.e. a fundamental (ω) together with the 3rd, 5th, and 7th harmonics. The resultant wave shows the approach to the square-topped condition. As more and more of the higher frequency odd harmonics are added, the undulations of the resultant wave become progressively less, and the wave more nearly approaches the square-topped form.

To be strictly accurate, allowance should also be made for the fact that the make and break portions of the standard impulse are not equal in length, but this modification to the Fourier's series does not alter the fact that any regular periodic wave

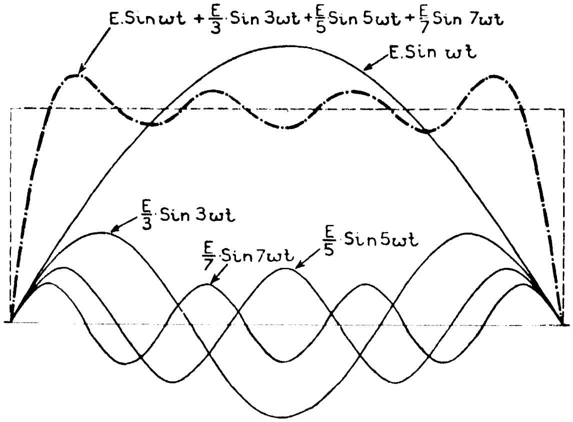


FIG. 652. SQUARE-TOPPED WAVE OBTAINED BY ADDING FUNDAMENTAL AND ODD-NUMBERED HARMONICS

can be represented by a fundamental sinusoidal frequency together with a number of similar sinusoidal waves of higher frequency and of the correct amplitude and phase relationship.

A detailed study of the propagation of complex waves along telephone lines is outside the scope of this volume. Briefly, there are three main effects:

(a) Any a.c. wave is attenuated during its passage along a telephone line. The degree of attenuation depends, amongst other things, upon the frequency of the wave.

(b) An a.c. wave travels along a transmission line at a definite velocity which is determined

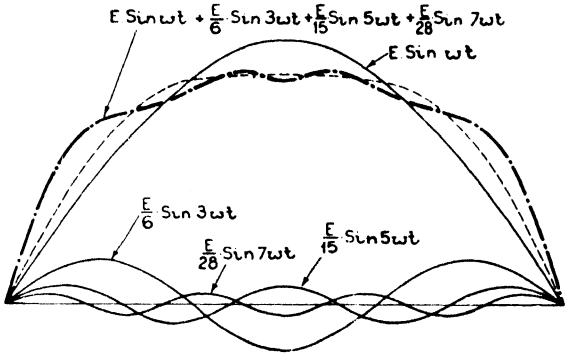


FIG. 653. SHOWING THE EFFECTS OF ATTENUATION OF THE HIGHER FREQUENCIES UPON IMPULSE WAVE SHAPE

partly by the electrical constants of the circuit and partly by the frequency of the wave. It follows that a.c. components of different frequencies have different transmission velocities and take different times to reach the distant end.

(c) Any alternating wave may be reflected at the ends of a line unless the circuit is correctly terminated to prevent such reflections. The effects of reflection differ for waves of different frequency.

Wave Attenuation. Any electrical wave is attenuated (i.e. its amplitude becomes less) as it proceeds along a line. This attenuation is, of course, due to the absorption of energy in the line resistance, and the shunting losses produced by leakance. The primary constants (inductance, capacitance, resistance, and leakance) of normal telephone lines are such that the degree of attenuation depends upon the frequency of the wave. As the frequency is increased, the attenuation also increases. The lower-frequency components of a complex wave are therefore attenuated to a less degree than the higher-frequency components. When the complex wave is in the form of a square-topped signal (as in impulsing), the higher attenuation of the upper frequencies produces a rounding off of the complex wave shape. This is illustrated diagrammatically in Fig. 653, which should be compared with Fig. 652.

It is possible to reduce the amount of attenuation and the rise of attenuation with frequency by "loading" the line with inductance coils at regular intervals. The provision of loading coils, however,

whilst minimizing the rise of attenuation at the lower frequencies, produces a cut-off effect so that the line will not transmit any frequencies above a critical value. The band width required for good commercial speech places a definite limit upon the amount of coil loading which can be applied to a line. A 20 lb unloaded star-quad cable has an attenuation of approximately 0·75 db per mile at a frequency of 500 c/s, whilst at 2000 c/s the attenuation is doubled (i.e. 1·5 db per mile). If this same cable is loaded with 44 mH coils at 2000 yd spacing, the attenuation over the range 0–4000 c/s rises from approximately 0·4 to 0·5 db per mile, but the circuit "cuts off" at some 4500 c/s

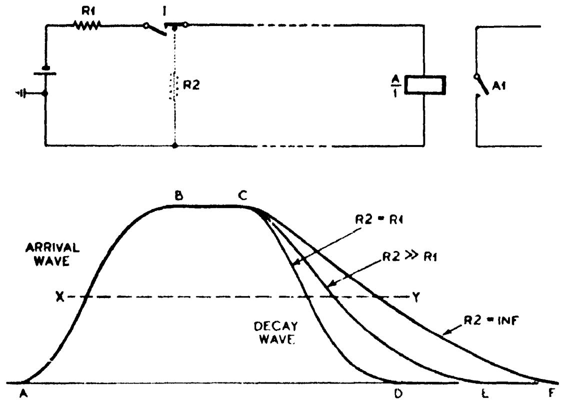


Fig. 654. Improvement of Wave Shape Obtained by "Closed Circuit" Impulsing System

so that no frequencies above this value can be transmitted.

Velocity of Wave Propagation. The velocity at which an electrical wave passes along a telephone line depends upon the primary constants of the circuit and upon the frequency of the wave. The characteristics of all normal telephone lines are such that higher frequencies are propagated at a greater velocity than the lower frequencies. For example, a sinusoidal wave of 300 c/s takes a period of some 40 microseconds to travel one mile through an unloaded 20 lb star-quad cable. A 3000 c/s wave passing along the same cable takes approximately 14 microseconds to travel the same distance.

We have seen that a square-topped signal consists of the fundamental impulse frequency plus a wide range of odd-numbered harmonics which bear a definite phase relationship to the fundamental frequency. The higher-frequency components travel faster and arrive at the distant termination before the lower frequencies, thereby modifying the relative phase relationship of the component parts of the complex wave. The effect of this phase shift is to produce a somewhat less square waveform at the distant termination. Broadly speaking, the effect of differing propagation times is substantially similar to the effect of the greater attenuation of the higher frequencies. Modification of wave shape due to phase change is not very great except on the longer trunk circuits routed over loaded cables. The differences in propagation time are not so marked for unloaded cables or for overhead lines.

Reflection. So far it has been assumed that a wave transmitted from one end of a circuit is propagated along the line and is completely absorbed at the receiving end. It can be shown that this condition can occur only if the line is made to behave as an infinitely long circuit. Approximately correct conditions can readily be provided on a speech circuit by arranging that the line is terminated at both ends by a critical value of impedance which is known as the *characteristic impedance* of the line. If these conditions do not exist, then reflection of the wave occurs at each termination of the circuit. The reflected waves pass backwards and forwards along the line until they are completely attenuated by the line losses. These reflection waves interfere with the initial wave so that the resultant waveform at any particular point can be materially modified.

With a loop-disconnect impulsing scheme the line is terminated by an inductive relay at the incoming end. During the make period between impulses, the line is short-circuited at the outgoing end, and during each break period this short circuit is replaced by a disconnexion, i.e. the transmitting end of the line is an open circuit. Very approximately it may be assumed that the extent of reflection depends upon the relationship between the terminating impedance and the correct (characteristic) impedance to give reflection-less transmission. Reflection effects are most pronounced when the lines are disconnected at the outgoing end during the transmission of a break impulse.

In Fig. 654 the more usual loop-disconnect impulsing circuit has been slightly rearranged to make it possible to vary the impedance of the sending end during the transmission of a "break" impulse. When the impulsing contact (*I*) operates, the rise of current in the impulse accepting relay (*A*) at the distant termination is shown by the curve *AB*. The shape of this curve is determined mainly by the attenuation and phase shift effects described in previous paragraphs. Reflection effects are minimized if resistor *R*1 and relay *A*

have impedances as near as possible to the characteristic impedance of the line. In loop-disconnect impulsing resistor $R2$ is not provided, i.e. when the impulsing contact releases at the commencement of a break impulse, the outgoing termination presents an open circuit to the line. Under these conditions the decay waveform of the current in the distant impulsing relay is very gradual as shown by curve CF (see also Fig. 649).

If a high valued resistor is now connected in position $R2$, the reflection effects at the commencement of the break period are somewhat reduced, and the resultant decay waveform is as shown by curve CE. As this resistor is reduced in value, the decay wavefront becomes more and more steep until, when $R2$ is made equal to $R1$, the decay wavefront becomes symmetrical with the arrival wavefront (i.e. $CD = AB$). The wave shape under these conditions is the best that can be obtained with given values of line constants. As will be seen later, the production of symmetrical arrival and decay waveforms makes possible distortionless repetition of the impulses if the impulse accepting relay can be adjusted to operate and release at the mid-height value (XY) of the current wave.

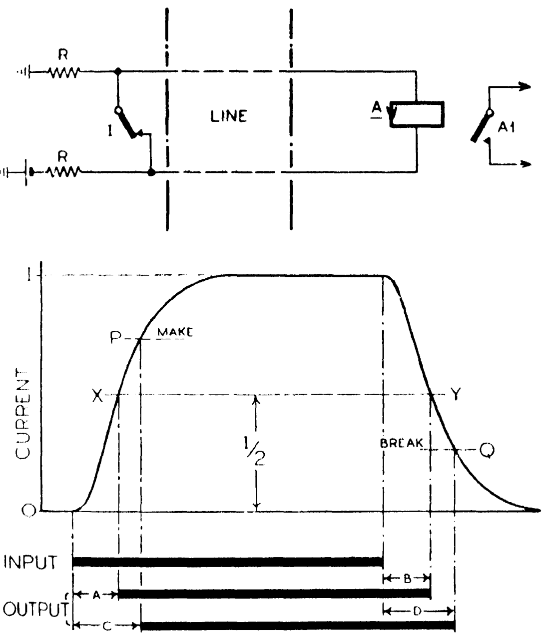


Fig. 655. Principle of Loop-battery Impulsing

Loop-battery Impulsing. The aim of maintaining a constant sending end impedance during impulsing can be achieved by the circuit arrangements shown in Fig. 655. This method might logically be called a *loop-battery* impulsing system. It will be noted that current is sent to line during the break of the impulsing contact, whilst the line is short-circuited during the make period of the impulsing contact. This is the reverse of the loop-disconnect impulsing

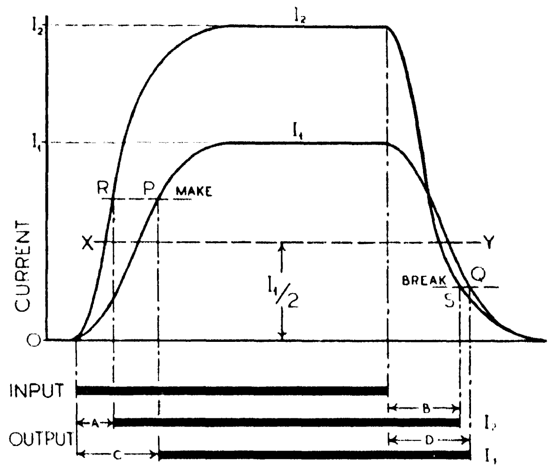


Fig. 656. Effect of Changes in Maximum Current Value

system. When impulsing contact I operates, the arrival curve of the current impulse is very much the same shape as that obtained when the contacts *make* in a loop-disconnect impulsing scheme. When the impulsing contact remakes at the end of the impulse, there is no material change in the impedance, and the decay wavefront is identical with the arrival wavefront.

The signal shape produced by a loop-battery impulsing circuit is shown diagrammatically in the lower part of Fig. 655. If a line XY is drawn at the mid-point across the impulse wave, the arrival and decay wavefronts are symmetrical about this line. It follows that, if an impulse accepting relay can be made to operate at a value X, and release at the same value Y, distortionless repetition of the impulse can be obtained. (Due to the symmetrical nature of the wavefronts, time A must be equal to time B.) With relays of the normal type, there is some difficulty in designing a relay which will operate and release at substantially the same value of current. Distortionless repetition can, however, still be obtained provided that the operate and release currents are arranged symmetrically about the centre line XY. For example, if the operate current is P and the release current is Q, there will be no distortion provided that XP is equal to YQ (i.e. $C = D$).

The operate and release currents of a relay are fixed by the mechanical design, and hence the

theoretical distortionless condition described above can obtain only for a particular value of line current. If the maximum signal amplitude has any other value, then the operate and release current values will no longer be symmetrical about the mid-point of the arrival curve. This is illustrated in Fig. 656 where the relay operate and release current values are adjusted to give distortionless repetition for a particular amplitude I_1 (i.e. $C = D$). If a higher amplitude pulse (I_2) is applied to this same relay, it will operate and release at the same current values, but these values are no longer symmetrical about the half-way line, and distortion occurs (i.e. $A < B$).

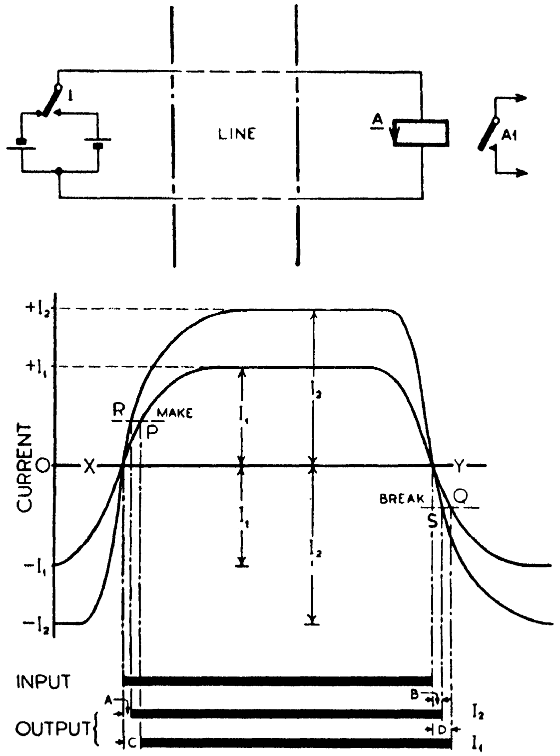


FIG. 657. PRINCIPLE OF DOUBLE-CURRENT IMPULSE SYSTEM

Any impulsing system in which the impulse accepting relay must be critically adjusted to a particular line condition is undesirable from a practical point of view, and it would be much more satisfactory if a scheme could be developed to make the impulsing relay performance more or less independent of the line characteristics and battery voltage.

Double-current Impulsing. The relay adjustment problem can be solved by shifting the centre line XY of Fig. 656 down to the zero current axis by the use of double-current signalling methods. Fig. 657 shows a simple method of obtaining double-current working by the use of two separate batteries and a single changeover impulse sending contact (I). The receiving relay must now be of the polarized type with a neutral-adjusted contact system.

The centre line XY has now become the zero datum line. When the impulsing contact operates, the current in the receiving relay changes from a maximum value in one direction to an equivalent value in the reverse direction. The time axis of the curve (XY) is therefore the mid-point of the complete waveform and, if the receiving relay is adjusted to operate and release at current values which are set equally about the zero datum line, there will be no distortion. This distortionless condition will apply (for the same relay adjustments) irrespective of the amplitude of the signal current. It should perhaps be mentioned at this stage that in using the word "distortionless" impulsing, no account has been taken of eddy currents, inertia, contact travel times, and other features of the receiving relay. There will, therefore, always be a certain amount of distortion, depending upon the physical design of the impulse receiving device.

One further advantage of the double-current system is the inherent sensitivity of a relay of the polarized type.

One of the difficulties of the double-current system illustrated in Fig. 657 is the necessity for two signalling batteries. Double-current effects can be obtained by the use of a single battery in conjunction with two changeover contact units. This system could be termed a *double-commutation* method, and is illustrated in Fig. 658. In all other respects it behaves in exactly the same way as a double-current system of impulsing. The great disability of the double-commutation method is, of course, the need for two synchronized changeover contacts ($I1$ and $I2$) of the impulse sending relay.

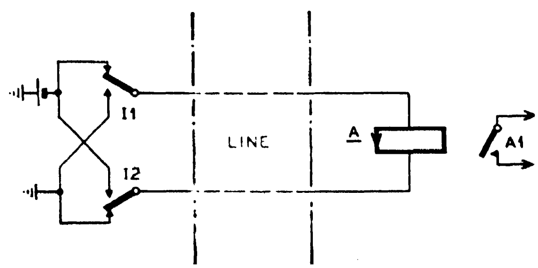


FIG. 658. DOUBLE-CURRENT EFFECTS FROM SINGLE BATTERY WITH TWO CHANGEOVER IMPULSING CONTACTS

Double-flux Commutation Scheme. Another method of obtaining double-current signalling effects is illustrated in Fig. 659. This circuit utilizes a single battery for signalling, but requires two changeover contacts at the outgoing end. These contacts are arranged so that battery and earth are applied to each line alternately. The impulse accepting relay is polarized and has two similar coils which are earthed at the centre-point. The line current produces symmetrical signals which energize the relay coils alternately, the resulting flux in the relay core being similar to that obtained with true double-current working. The disadvantage of the double-flux commutation scheme lies in the difficulty of accurate synchronization of the two separate changeover contacts at the transmitting end and of designing a relay which is sufficiently sensitive to operate satisfactorily over long lines (only one-half of the winding space is effective).

Double Counter E.M.F. Scheme. The double counter e.m.f. scheme illustrated in Fig. 660

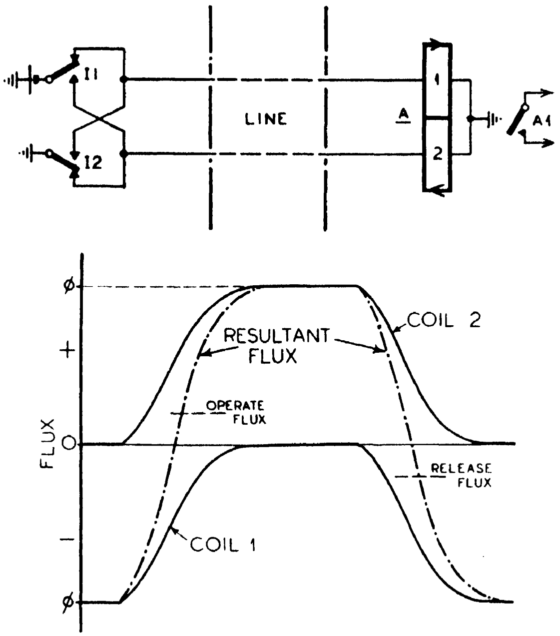


FIG. 659. DOUBLE-FLUX COMMUTATION SCHEME

utilizes a polarized accepting relay, two transmitting batteries and a single make impulsing contact. In this scheme, the two coils of the receiving relay are connected to battery and earth as in loop-disconnect impulsing. This feature has some advantages in that it facilitates the provision of supervisory, etc., signals without the need for complicated switching arrangements. If it is assumed that the e.m.f. of the battery at the incoming end is $E1$, and the e.m.f.s of the batteries at the transmitting end are $E2$ and $E3$, then for correct operation $E2$ must equal $E1/2$, and $E3$

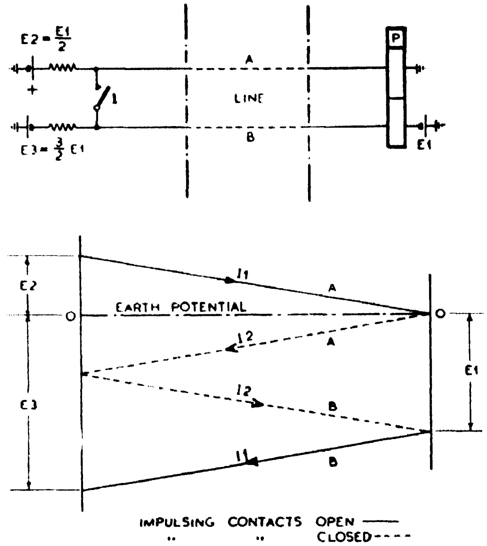


FIG. 660. DOUBLE COUNTER E.M.F. IMPULSING SCHEME

must be equal to $3E1/2$. When the impulsing contact I is closed, the outgoing ends of both lines are looped, and have a potential of $E1/2$. The potential gradients and currents in the two lines and relay coils are now equal. The release of I applies a change of potential of $E1$ to each of the two lines (positive for one and negative for the other), and the resulting currents are equal and opposite to those previously flowing.

The double-current counter e.m.f. scheme relies on the accurate adjustment of the voltages at the outgoing and incoming ends of the circuit. The scheme is therefore subject to the rather serious disadvantage that any variation in these battery voltages affects the fidelity of the repeated signals. Moreover, batteries of suitable voltage for use at the transmitting end of the circuit are not normally available at an exchange, and the provision of special batteries for this purpose is a further difficulty in practice.

Differentiated Impulse System. If means can be found whereby single-current line signals can be converted to double-current type signals at the receiving relay, then the advantages of double-current working could be achieved whilst retaining the simplicity of the impulse sending element of the single-current system.

One method is to differentiate the arrival and decay current wavefronts by means of a transformer. The voltage surges across the secondary winding of this transformer accurately mark the beginning and end of each line signal. The surge at the commencement of an impulse is in the opposite direction to the surge at the end of the impulse, so that double-current effects are obtained. Unfortunately the power output from the secondary of the line transformer is insufficient to permit the operation of a relay direct in the secondary circuit, and hence it is necessary to provide a valve amplifier with a polarized relay in the anode circuit.

The termination of the line on an inductive transformer winding also materially improves the signal wave shape. We have seen that the higher-frequency components of the transmitted signal are appreciably attenuated during transmission over a long circuit. The reactance of any inductance increases with the frequency of any applied current. Hence, when a long circuit is terminated by an inductance, the increase of terminal impedance with frequency compensates to some degree for the increase of line attenuation with frequency. The net result is that steep voltage wavefronts across the inductance can be obtained.

A long-distance impulsing system employing the differentiated impulse system has been developed and has been used to some extent in this country. Fig. 661 shows the elements of the scheme which has become known as L.D.D.C. Dialling (*Long-Distance Direct Current Dialling*). At the sending end of the circuit the simple break contact provides loop-battery impulsing conditions to line. The line is terminated at the incoming end on the primary of a transformer, the secondary of which is connected to the grid of a triode valve. The rise of current in the primary winding of the transformer (on receipt of a current impulse) causes a sharp surge of current in the secondary winding. The polarized relay *PR* in the anode circuit is connected so that the current in the 1600 Ω winding tends to release the relay, whilst that in the 108 Ω winding tends to operate the relay. The valve is biased as for an ordinary amplifier, and in the quiescent condition the anode current is sufficient to release *PR* against the effect of the current in the 108 Ω winding. Relay *HSA* is energized under these conditions, and contact ***HSA*1** provides the impulsing loop forward.

The surge in the secondary winding of the transformer, due to the commencement of a current pulse in the line, increases the negative

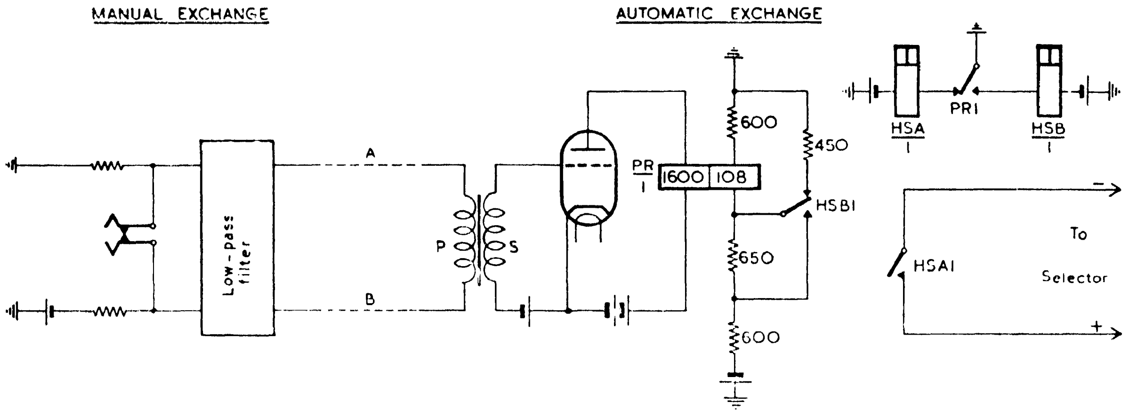


FIG. 661. PRINCIPLE OF DIFFERENTIATED IMPULSE SYSTEM

bias on the grid of the valve to produce a momentary reduction in the anode current. *PR* now operates due to the preponderance of the current in the 108 Ω winding, and at ***PR*1** releases *HSA* and energizes *HSB*. ***HSB*1** increases the current in the 108 Ω coil of *PR* to provide a safe holding circuit for *PR* in readiness for the termination of the pulse.

When the impulsing contact closes, the voltage surge in the transformer secondary is in the opposite direction, and the positive signal on the grid produces a momentary increase of current in the anode circuit. The currents and turns are adjusted so that the higher current in the 1600 Ω winding overcomes the effect of the augmented current in the 108 Ω winding. *PR* now releases, and at *PR*1 re-operates *HSA* to terminate the break impulse. Fig. 662 illustrates the operation of the circuit.

The differentiated impulse system gives a good performance on long underground lines of up to 100 miles in length, but it suffers from certain

disadvantages. In the first place, the differentiating action of the input transformer makes the system somewhat liable to false operation due to external interference. (A comparatively small voltage change on the line can produce an appreciable voltage in the secondary winding of the transformer if the *rate of change* of the interference voltage is sufficiently great.) In addition, the differentiated impulse system somewhat complicates the arrangements for the transmission of calling, clearing, supervisory and other signals which are required on a junction circuit. It is, in fact, necessary to arrange for switching from the signalling to the impulsing circuit, and vice versa, as the call proceeds. The necessity for a valve in

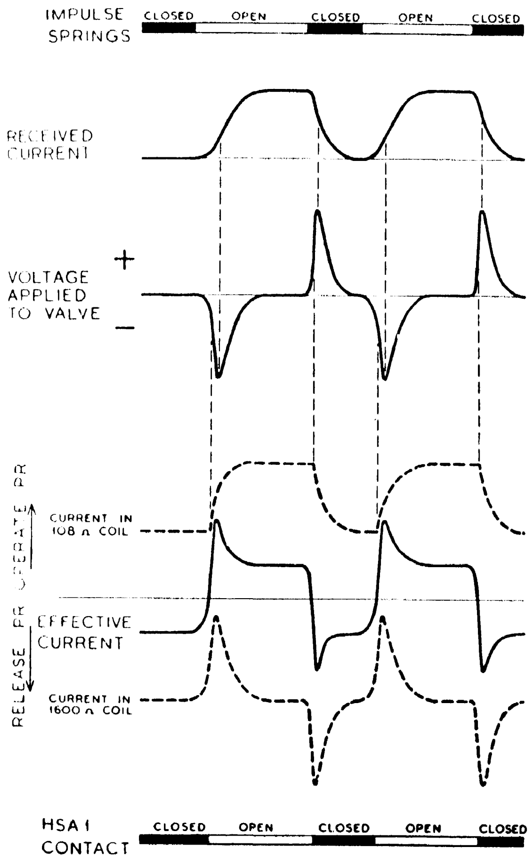


FIG. 662. DIAGRAMMATIC ILLUSTRATION OF CONDITIONS IN DIFFERENTIATED IMPULSE SYSTEM

the receiving equipment also adds to the cost of the system.

Single Counter E.M.F. Valve Scheme. Fig. 663 shows another interesting scheme, which requires only a single battery and a simple make contact at the transmitting end. The transmission of the signals to line follows the loop-battery principle already described, and produces symmetrical

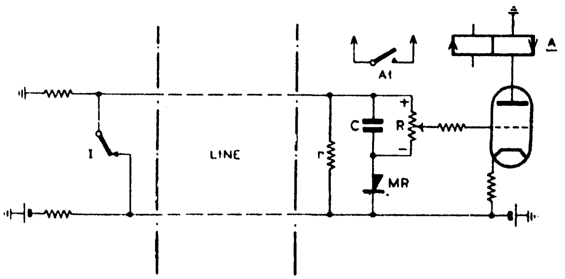


FIG. 663. PRINCIPLE OF SINGLE COUNTER E.M.F. VALVE IMPULSING SCHEME

wavefronts. The line is terminated by the resistor *r*, and the voltage across this resistor varies in accordance with the waveform of the line current. The received signal charges capacitor *C* via rectifier *MR*. The resultant potential across the capacitor is substantially equal to the voltage across the line terminating resistor (*r*). The potentiometer (*R*) is of very high resistance so that, when the line current ceases, there is no appreciable discharge of *C* during the interval between successive signals. (The impedance of the metal rectifier is very high in the direction of the discharge currents.) Thus, the voltage across *R* is nominally equal to the maximum value of the signal.

By adjusting the moving contact of the potentiometer near to its mid-point, the valve can be biased to a voltage equal to half the signal amplitude. The signal waveform thus applied to the valve has equal positive and negative portions, and the anode current changes by equal amounts about the no-signal value. By a suitable choice of component values, a double-current effect is obtained over a sufficiently wide range of signalling levels.

The main disadvantage of this scheme is the variation in performance due to the change in valve characteristics. Moreover, the cost of the valve and the continuous energy consumption of the heater circuit further reduce the attractiveness of the scheme.

Single-commutation D.C. Impulsing. True double-current signalling can be obtained from a single battery and a simple changeover impulsing contact by the single-commutation method illustrated in Fig. 664. When the impulsing contact is in its normal position, earth is applied to one line, and negative battery is sent out on the second line. When this contact changes over, the conditions are reversed so that the line current flows in the

opposite direction. The receiving element is a polarized relay. Theoretically this relay should be adjusted in its neutral position so that the alternate operate points are equally spaced about the zero axis of the current waveform. If this can be

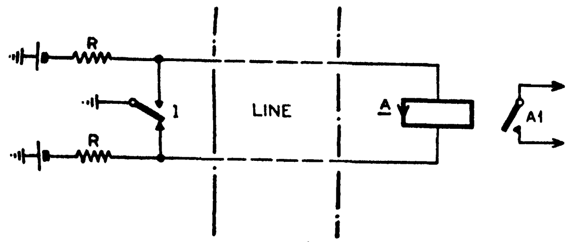


FIG. 664. PRINCIPLE OF SINGLE-COMMUTATION D.C. IMPULSING

arranged, then distortionless impulsing can be obtained in a very simple and straightforward manner.

One of the chief merits of single-commutation impulsing is the ease with which the normal junction signalling requirements (e.g. calling, supervision, release, etc.) can be associated with the impulsing element. Impulsing is effected by signals *round* the telephone loop (i.e. transverse currents). The initial loop signal prior to impulsing can be used as a calling or seizure signal, whilst the removal of this loop at the end of the call can be used to give a release signal to the distant equipment. By providing two coils on the polarized relay it is possible to return earth or battery signals over both wires in parallel to give busy flash and answering signals. By the adoption of a balanced circuit arrangement, these battery and earth signals can be transmitted satisfactorily without interfering with the forward loop signals from the outgoing end.

Fig. 665 shows the essential elements of a single-commutation impulsing system which includes supervisory facilities. In the idle condition current flows from the earth at *MRD* via one coil of relay *AP*, the *A*-wire of the trunk circuit, one coil of relays *IS* and *DP*, to the battery at resistor *YA*. This current holds relays *AP* and *DP* in the released position (as shown) and operates relay *IS*. When the circuit is seized, the operation of relay *A* to the calling loop causes contact **A1** to change over, thereby ceasing the current on the *A*-wire of the circuit and causing a similar current to flow over the *B*-wire of the circuit and the second coil of relay *AP*. This second coil of relay *AP* is connected so that the passage of the current over the *B*-wire causes *AP* to operate. **AP1** energizes the guard relay *B* and the relief impulsing relay *AA*. Contact **AA1** now seizes the incoming selector by extending forward the *D* and *I* relay loop. Relay *I* operates to the loop current.

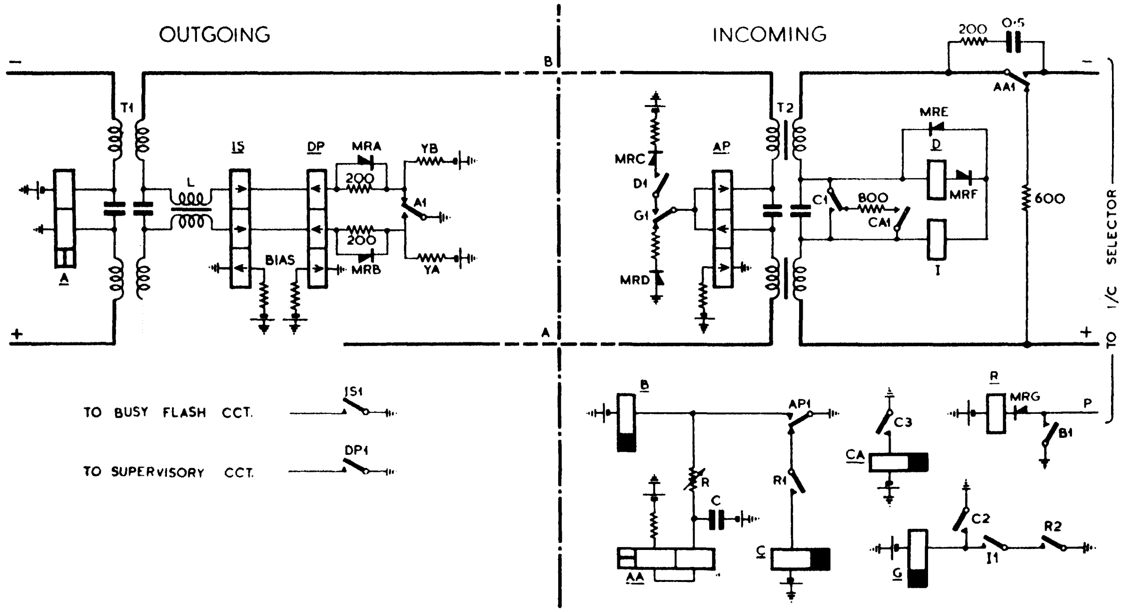


FIG. 665. ELEMENTS OF S.C.D.C. IMPULSING SCHEME WITH SUPERVISORY SIGNALS

The operation of relay *B* completes, at **B1**, a circuit for relay *R* which now holds to the earth

returned from the incoming selector over the P-wire. ***R*1** prepares the operate circuit for relay C, whilst ***R*2** and ***I*1** together complete a circuit for relay G. ***G*1** in turn disconnects the earth from the centre-point of the AP relay in readiness for impulsing, thereby releasing relay IS at the outgoing end.

Relay C operates at the first break impulse and at ***C*1** short-circuits the D and I relays in order to exclude them from the impulsing path. ***C*3** energizes the relief relay CA (which is required to provide a two-stage drop-back), whilst ***C*2** provides an alternative holding circuit for relay G to cover the release of I during impulse trains. At each interdigit pause relays C and CA release, but relay G is held due to the interworking of contacts ***C*2** and ***I*1**. Relays IS and DP are unaffected by the currents during impulsing due to the balance of current in the two windings.

After the setting up of the call, relay D operates in response to the answering signal from the called subscriber. ***D*1** applies battery to the centre-point of relay AP. (G is held at this stage via ***I*1** and ***R*2**.) At the outgoing end of the circuit the B-wire is connected to battery via YB, whilst the A-wire is connected to earth at **A1**. The application of the battery to both wires at the incoming termination causes current to flow in the A-wire but, since both batteries are in opposition, no current flows over the B-wire. The connexions of relays IS and DP are so arranged that the current over the A-wire operates relay DP but does not operate IS. Contacts of DP now apply supervisory conditions to the calling party (details of this circuit are omitted for simplicity). Relay AP, which was held by virtue of the current in its two coils in series prior to the answer condition, is now held over one coil by the current over the A-wire of the trunk circuit. This current is of twice the magnitude of the previous loop current, and hence there is no change in the number of ampere-turns holding relay AP during answer conditions.

At the end of the call, relay D releases when the called subscriber clears, but relay I remains held to the forward loop current. ***I*1** in turn holds relay G so that the battery condition on the centre-point of relay AP is replaced by a disconnexion. The current on the A-line is now replaced by equal loop currents over the A- and B-lines which hold relay AP over both coils in series. The current returned over the B-wire, however, releases relay DP due to the differential action of the two windings of the latter. Contacts of relay DP give a clearing signal to the calling party.

In due course relay A releases in response to the forward clearing signal, and at $A1$ reverses the current in the A- and B-wires of the trunk circuit. Relay AP now releases, and at $AP1$ releases relays AA and B. $AA1$ disconnects the forward holding loop to the selector train. The release of $AP1$ re-operates relay C, and **C2** provides an alternative holding circuit for relay G. **C3** operates relay CA. When the associated incoming group selector restores to normal, relay R releases and at $R1$ releases C. $C3$ in turn releases relay CA, whilst $C2$ releases relay G. $G1$ now re-applies earth to the centre-point of relay AP to restore the circuit to normal. (The restoration of the earth condition to the centre-point of relay AP, when all the incoming equipment has restored to normal, operates relay IS to provide an extended busying condition to guard against premature seizure before the incoming equipment has completely restored from the previous call.)

If engaged conditions are encountered during the setting up of a call, relay I releases during each period of busy flash. $I1$ in turn releases relay G, and $G1$ applies earth to the centre-point of relay AP. Since contact **A1** is operated, current flows via one coil of relay AP and the B-wire of the junction to the battery at resistor YB, no current passing over the A-wire due to the presence of the two earth conditions. Relay AP holds to the B-wire current, and this same current operates relay IS but not relay DP in the outgoing termination. Contacts of relay IS repeat the busy flash signal towards the calling party. Relay IS re-operates after the flash period and, by re-operating relay G, changes over to the loop signalling condition at the centre-point of relay AP. This process continues during each period of flash until the call is abandoned.

The impulsing relief relay AA at the incoming termination is energized through a capacitative network which contains a variable resistor. This arrangement provides some measure of control over the operate and release times of relay AA, so that correction can be made for impulse distortion on a particular line. It is also possible to compensate for the incremental transit time of relay AP by adjustment of the current in the bias winding. The contact transit time of this relay depends, amongst other things, upon the steepness of the arrival and decay wavefronts, and hence a fixed bias cannot completely compensate for all variations of signal shape. By suitable design it is, however, possible to adjust the bias to provide a good compromise on lines of various characteristics.

A pair of resistors are connected to the line side of the transmitting contact and are shunted by metal rectifiers MRA and MRB. The rectifiers are so connected that MRA offers a high impedance

and *MRB* offers a very low impedance to the line currents when contact *A*1 is normal. When *A*1 operates, the polarization of the rectifiers is reversed. If all four resistors of the outgoing end are made of equal value, this circuit arrangement ensures that the sending impedance of the transmitting element is the same, irrespective of whether *A*1 is operated or normal. (We have seen earlier that a constant sending end impedance is necessary to produce symmetrical wavefronts.)

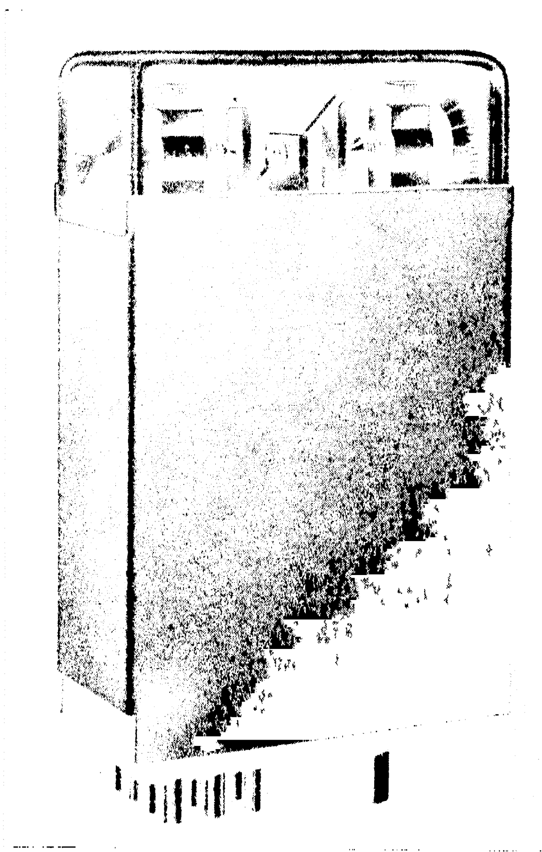


FIG. 666. CARPENTER TYPE 4A RELAY

The single-commutation impulsing system is designed for use on very long underground lines, and the circuit arrangements must therefore take account of the possibility of differences in the earth potential at the sending and receiving ends. Various tests have indicated that, under normal conditions, up to 0·3 V per mile may be encountered. Hence, if the system is to work satisfactorily up to distances of 100 miles, it is clear that there may be substantial differences of earth potential. The loop signalling circuit is not susceptible to differences of earth potential, but such potentials may interfere with the earth and battery signals returned from the incoming end. The rectifiers *MRC* and *MRD* are included in the earth signalling circuit to minimize the effect of differences of earth potential whilst, at the same time, permitting the normal signalling currents to pass without hindrance.

The choke *L* (of approximately 5 H inductance) is included in the sending circuit in order to steepen the current waveform, whilst the transformers *T*1 and *T*2 are specially designed to maintain a good standard of speech transmission but to minimize the transmission of surge disturbance along the several links of a connexion.

The distance over which it is possible to signal satisfactorily is limited by the resistance of the line which determines the contact pressures on the signalling relays. A further limiting factor is the impulse repetition distortion, which becomes noticeable on lines of high resistance and appreciable capacitance. The system as at present developed will work with less than 0·3 msec distortion over the normal speed and ratio limits for lines whose time constant (CRL^2 value) does not exceed 76 msec. This corresponds to a non-loaded phantom circuit of up to 100 miles of 20 lb P.C.Q.T. cable. The loop resistance of such a line is approximately 4400 Ω.

Impulsing Relays. The ultimate limit of a long-distance d.c. impulsing system is determined by the sensitivity of the receiving relay. This relay must operate with very small values of line current and must provide satisfactory contact pressures under these conditions. The relay must, moreover, be easily adjustable to within fine limits and the adjustments must remain stable during service. Relays of the ordinary telephone type are totally unsuitable owing to their poor sensitivity and the comparative crudeness of the adjustments. Fig. 666 gives a general view of the Carpenter Type 4A polarized relay which is particularly suitable for long-distance d.c. impulsing. The relay is designed to mount in the same space as the standard 3000 type relay. It is totally enclosed by a magnetic screen, a transparent plastic top being provided so that the contact system can be inspected without removing the cover. Fig. 667 shows the relay with the cover removed. A high degree of sensitivity is obtained by the adoption of a very efficient magnetic circuit. The armature is mounted on springs at the centre of gravity (i.e. there are no pivots). Particular regard has been paid to the avoidance of contact bounce by the provision of damped compliant mountings for the side contacts.

Fig. 668 shows the arrangements of the magnetic circuit in diagrammatic form. There are two permanent magnets mounted near the point at which the armature is suspended. The flux from these magnets traverses the armature in a longitudinal direction and returns via the air gap at the lower extremity of the armature. The flux from the line coil merely passes through the lower armature air gap and across the *width* of the armature. The portion of the magnetic circuit which carries the variable fluxes resulting from line signals is therefore extremely simple with only a single air gap in which the armature is situated. By making this

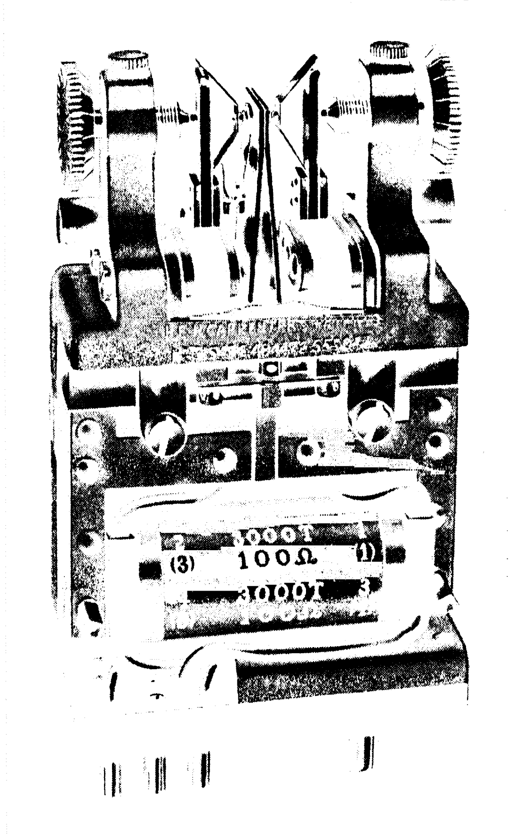


FIG. 667. CARPENTER TYPE 4A RELAY WITH COVER REMOVED

air gap as small as possible the total reluctance of the variable flux path can be made small so that there is a maximum flux change for a given change of magnetizing force. The cross-section of the core of the line coil need only be large enough to carry the variable fluxes, and this in turn makes it possible to reduce the diameter, and hence the resistance, of the coil winding. The reluctance of the upper pair of air gaps has to be overcome only by the static flux from the permanent magnets, and

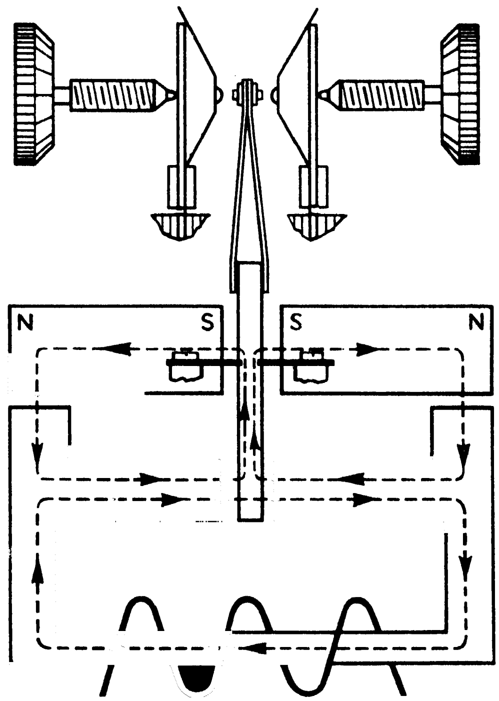


FIG. 668. MAGNETIC CIRCUIT OF CARPENTER RELAY (DIAGRAMMATIC)

these air gaps can be made comparatively wide (30 ± 4 mils). Only the lower armature air gap need be kept small (8 ± 3 mils) to obtain a high degree of sensitivity. When current is passed through the line coil the resultant flux in the lower portion of the magnetic circuit assists the permanent magnet flux on one side of the armature and opposes the permanent magnet flux on the other side of the armature, thereby causing the latter to move either to the right or to the left (depending upon the direction of the current in the line coil).

The sensitivity of the relay does, of course, depend upon the extent of armature travel, i.e. upon the length of the contact gap. The following are typical figures for the *absolute* sensitivity of the relay:

Contact Gap (mils) .	1	2	3	4	5	6
Operate Ampere-turns .	1·1	2·2	3·4	4·5	5·6	6·8

The normal working *contact gap for telephone purposes* is 3 ± 1 mils. Although the above figures *indicate* the absolute sensitivity of the relay, it is desirable to work with higher values of excitation in order to provide adequate contact pressures. A practical figure of 9 ampere-turns as the minimum operating excitation will provide contact pressures of the order of 18 g with a 3 mil contact gap. The winding will dissipate some 3 W of energy, and magnetic saturation occurs at about 60 ampere-turns. A typical relay of 100 Ω resistance contains some 4100 turns of No. 37 S.W.G. enamelled wire.

The inductance of the relay is given by the following approximate formula:

$$\text{Inductance} = Kn^2 \text{ henries}$$

where n = turns,

K = a constant $= 3 \times 10^{-7}$.

The contacts are made of a copper palladium alloy (60–40). To ensure complete freedom from contact bounce, the "anti-chatter" springs are given a tension of 20 ± 3 g against the buffer plates.

VOICE-FREQUENCY DIALLING

The limited sensitivity of the receiving relay prohibits the use of direct current dialling methods on the longer trunk circuits. Moreover, the trend of development is towards the use of carrier transmission systems on all except the shorter zone-to-zone links of the trunk network. In some of these carrier systems, one pair of conductors may serve to carry 12 or 24 separate speech channels. In other systems the cable is of coaxial construction and one such coaxial tube may carry upwards of 500 simultaneous calls. From a signalling point of view a common feature of all carrier systems is the joint use of the physical metallic conductors by a number of separate traffic circuits. The absence of separate physical conductors for each circuit makes it virtually impossible to employ any form of direct current signalling. Each channel of a carrier system must, of course, provide for the transmission of a range of alternating currents to cover the band necessary to give good commercial speech. The internationally agreed standards for speech transmission provide for a speech-frequency range of 300 c/s to 3400 c/s. All modern transmission systems meet these requirements, but there are still a number of the older transmission lines where the upper limit is somewhat lower. It is clear that any alternating current within the frequency range of the transmission system can be used for signalling purposes. Such signalling currents are readily transmitted through the electronic valve circuits provided for speech amplification, thereby providing compensation for the attenuation of the signalling currents as they pass along the trunk circuit. When the speech circuit is also used for the transmission of signals, it follows that the signalling currents must be of comparable power to that of the speech itself.

The idea of signalling over long distance by means of voice-frequency currents is by no means new. In the United States of America several systems were developed in the early twenties, and this was followed by comparable systems in Great Britain and in various European countries between 1925 and 1930. Most of these earlier systems were designed to provide calling and supervisory signals between terminal exchanges of the manual type. The continued process of automatization of local exchange networks soon brought with it the desirability of providing means whereby dialling signals could be transmitted over long trunk circuits. These developments led to the introduction in 1937 of a system of dialling from zone centre manual boards to the automatic equipment at distant zone centres. Since the second world war the desirability of complete automatization of the trunk network has become more urgent due to the shortage of equipment at the manual trunk switching centres. Plans are now in hand for the extension and improvement of the existing voice-frequency dialling scheme throughout the network.

Generally speaking, voice-frequency signalling systems may be broadly classified under three main headings:

(1) Systems where the signalling currents are transmitted on the speech channel.

(2) Systems where the voice-frequency signalling currents are transmitted over a separate channel to that used for speech.

(3) Systems where part of the frequency spectrum is removed from the speech circuit and allocated for the use of the signalling currents.

The problems associated with each of these three methods are discussed in later paragraphs, but in the meantime it is desirable to examine some of the basic principles involved in the transmission and detection of alternating V.F. impulse signals.

Propagation of V.F. Pulses. We have seen in earlier paragraphs of this chapter that a d.c. impulse signal may be considered as a sinusoidal a.c. wave (at the impulse frequency) on which is superimposed a very wide range of odd-numbered harmonics. The transmission of the d.c. signal can be examined by observing the effects, during transit, on the various component frequencies. A short pulse of voice-frequency tone may somewhat similarly be considered as a continuous tone of the

signal frequency which is modulated by a square-topped wave of the impulse frequency (Fig. 669). If the impulse frequency were sinusoidal, this modulation would produce several further frequencies, e.g. frequencies equal to the sum and difference of the two original frequencies. The modulating wave is, however, square-topped and may be considered as comprising a wide range of odd-numbered harmonics in addition to the fundamental frequency. All these harmonics have a modulating effect on the voice-frequency current, so that the total result of the modulation is a very wide range of frequencies extending from 10 to infinity.

From a transmission point of view, therefore, a pulse of voice-frequency tone which has a square-topped envelope as in diagram *C* (Fig. 669) must be considered as comprising a very wide range of component frequencies in addition to the signal frequency itself. All the products of the original modulation are subject to attenuation, phase displacement and reflection in the course of transmission over a long trunk circuit. As a result the envelope of the received V.F. signal (*D*, Fig. 669) has arrival and decay wavefronts substantially similar to those of a d.c. impulse. It is of some importance to appreciate that a square-topped V.F. pulse contains many other frequencies in addition to that of the signalling tone supply. Such components as electrical filters may have a material effect on the overall shape of the envelope due to the attenuation of these "hidden" component frequencies.

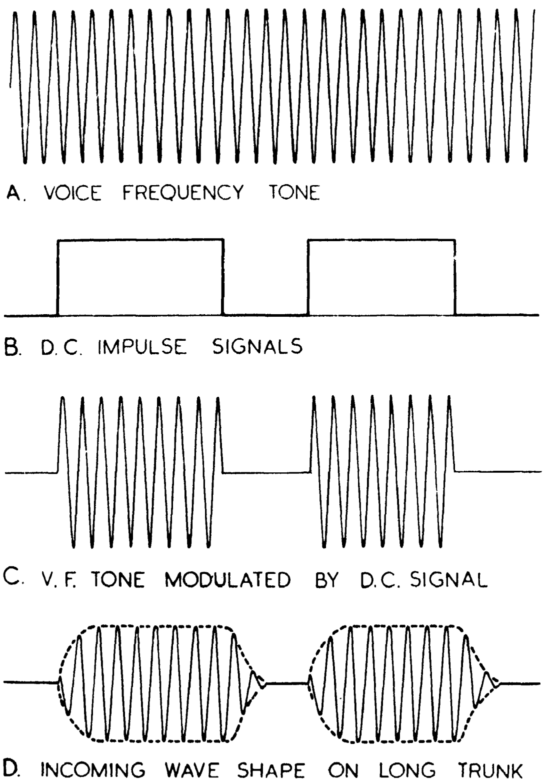


FIG. 669. MODULATION OF V.F. TONE BY IMPULSING SIGNALS

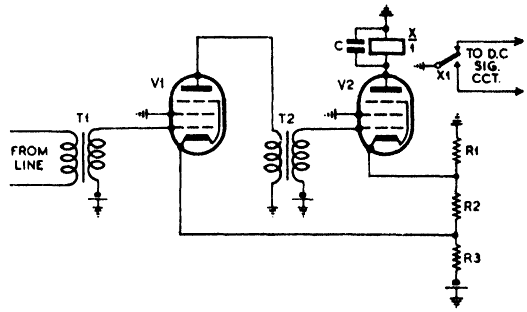


FIG. 670. SIMPLE RECEIVER CIRCUIT WITH ORDINARY TELEPHONE RELAY IN CIRCUIT OF ANODE-BEND DETECTOR VALVE

The Detection of V.F. Signalling Currents. Mechanically tuned relays, of the type used in the 4-frequency keysending system designed for local areas, are unsuitable for use as detection devices on long-distance trunk circuits. Such resonant relays will operate satisfactorily only if the incoming signal level is maintained within close limits, which are not generally obtainable on long trunk circuits. Moreover, mechanically tuned relays have a comparatively long "build up" time before the mechanical system attains the requisite amplitude of vibration. They are therefore of little value to receive impulse trains where the duration of each impulse must be maintained within fairly close margins.

The only practicable detection device for use on a long-distance V.F. impulsing system is an electronic valve circuit which incorporates some form of electromechanical relay for the repetition of the signals as d.c. impulses. Fig. 670 shows a simple V.F. receiving circuit utilizing two pentode valves and an ordinary telephone relay. The equipment is usually required for use in telephone exchange buildings where the normal power supply is a 50 V battery with the positive pole earthed. It is generally desirable that this battery should be made to serve as the anode current supply to the V.F. receiving units in order to save the

provision of separate power plant. The incoming voice-frequency signal is applied to the input transformer $T1$, the secondary winding of which is connected to the control grid of the first valve $V1$. This valve is biased as for an ordinary amplifier,

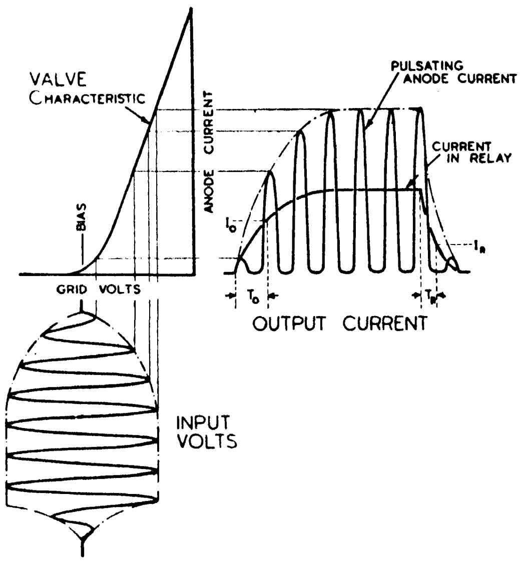


Fig. 671. V.F. Signal Applied to Anode-bend Detector Stage

and any impressed a.c. voltage on the grid results in a fluctuating current in the anode circuit and hence in the primary winding of transformer $T2$. The varying currents in the primary winding of $T2$ in turn produce an alternating voltage on the grid of the second valve $V2$. This valve is biased back so that, in the absence of an incoming signal, the anode current is negligible. Positive half-cycles of an impressed a.c. voltage reduce the effective negative bias on the control grid and thereby produce comparable half-wave pulses of anode current. A relay (X) is included in the anode circuit and is shunted by a capacitor C which smooths the fluctuating d.c. pulses.

The operating conditions of $V2$ are illustrated diagrammatically in Fig. 671. On a long-distance circuit the envelope of an incoming V.F. pulse is somewhat of the shape shown in the lower part of the illustration. The application of this pulse to the grid of $V2$ produces a unidirectional pulsating current, the envelope of which is similar to the shape of the input signal. Due to the action of the capacitance across the relay, the effective current through the latter is as shown by the full line in Fig. 671. If I_O is the operate current of the relay and I_R is the release current of the relay, the operate and release lags are determined by the distances T_O and T_R respectively.

It is clear that, with a simple amplifier and anode-bend detector circuit, the degree of impulse distortion (as measured at contacts $X1$) is dependent upon:

(a) The envelope shape of the incoming V.F. signal.

(b) The maximum amplitude of the incoming signal.

(c) The slope of the valve characteristic (i.e. its mutual inductance).

(d) The anode and grid voltages.

(e) The operate and release current values of the relay.

In practice these various factors make it extremely difficult to adjust and maintain the circuit so that it will repeat the V.F. signals with limits of distortion which are within the necessary tolerances. It is therefore necessary to introduce various devices in the receiving unit to make the response and the degree of distortion less dependent upon such factors as incoming signal strength, valve gain, and so on.

Voltage Limitation and Receiver Stabilization. The voltage passed on to the detector stage of the receiver can be made less dependent upon the level of the incoming signal if the first valve of the receiver is designed to incorporate some form of voltage limiting device. There are many methods of limiting the output voltage of an amplifying valve. Some of these methods utilize a feed-back circuit so designed that the degree of feed-back is a function of the output voltage. (The A.V.C. system of an ordinary radio receiver usually incorporates a voltage limiting device of this type.) Some degree of voltage limitation can be obtained

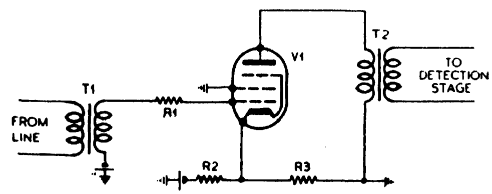


Fig. 672. Simple Voltage Limiter Stage with High Resistance in Grid Circuit

with an ordinary amplifier circuit if the bias is adjusted so that high level signals overload the valve. The effect can be made somewhat greater by the inclusion of a high resistance in the control grid circuit as shown in Fig. 672. The circuit values are so chosen that, when a high a.c. voltage is induced into the secondary winding of transformer $T1$, the effective bias on the control grid is reduced

to the point where grid current commences to flow. This grid current traverses the high series resistance $R1$, and in so doing produces a potential drop which opposes the induced e.m.f. in $T1$. The net result is that the circuit will accept incoming signals up to a critical voltage (i.e. that at which grid current commences to flow) without limitation, but any higher impressed voltages cause a comparatively small increase in the maximum value of anode current.

A slightly different voltage limiter circuit is shown in Fig. 673. In this case the valve ($V1$) is arranged to have zero (or a slightly positive) grid bias, and a high resistance R shunted by a capacitor C is included in the grid circuit. In the absence of an incoming signal, the circuit is stable at a point where grid current just commences to flow. If an a.c. signal is now applied to the input of the transformer, grid current will flow on the positive grid swings, and the potential drop across the resistor R will cause a steady potential to be developed on capacitor C. The direction of this potential is such that negative bias (of a value almost equal to the peak a.c. voltage) is applied to the grid of the valve. This potential rapidly builds up to the point when the anode current is reduced to zero. Any further increase in the level of the signal does not materially affect the magnitude of the grid swing or of the pulsating anode current. The conditions with small and large input signals are shown in the power portions of the illustration.

Both the voltage limiting circuits so far described are designed to produce a more or less steady voltage to the detector stage when the amplitude of the incoming signal varies over a comparatively wide range. The circuits do not compensate for changes in valve characteristics which may occur during service, and which may result in appreciable differences in the amplitude of the signal passed on to the detection stage. Such variations caused a considerable amount of trouble in some of the earlier designs of V.F. receivers, and it was necessary to "age" the valves in order to obtain reasonable stability of operation during service. The effects of changes in valve gain, and also of differences in input signal level, can be minimized by the introduction of an independent voltage limiting circuit between the amplifying valve and the detection stage. A common form of voltage limiter used in such circumstances consists of a suitable rectifier shunted across the signal path. The rectifier is so biased that, with signals of up to a certain critical value, the static bias on the rectifier predominates and the rectifier itself offers a very high shunt impedance. If the signal level exceeds this critical value, the direction of the bias on the rectifier is reversed, so that it offers a comparatively low impedance and thereby shunts

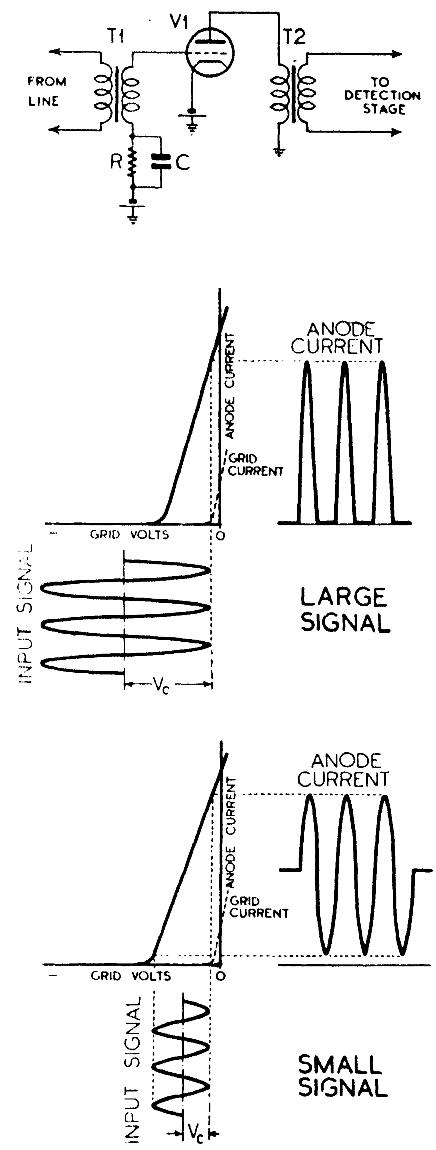


Fig. 673. Voltage Limiter with Capacitor in Grid Circuit

away the excess peaks of the signal voltage. Fig. 674 shows a typical rectifier limiting or stabilizing circuit utilizing a diode valve. The component values are so chosen that the bias on the diode ($E1$) is equal to the maximum signal voltage which is

to be applied to the detection stage. If the impressed voltage (E) is less than $E1$, the anode of the diode is always negative in respect of the

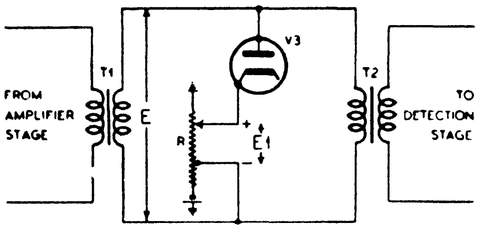


Fig. 674. Voltage Limiter Circuit Utilizing Diode Valve

cathode, so that there is substantially no shunting loss. When, however, E exceeds the value of $E1$, the anode becomes positive to the cathode, and the resultant current through the diode shunts away the energy of the excess voltage. A metal rectifier can be used in place of the diode if so desired, the main requirement being a low impedance in the conducting direction in relation to the remaining impedances of the circuit.

Relay Operating Valve Stage. The simple anode-bend detection circuit so far considered (Fig. 670) may produce considerable impulse distortion even if the input voltage from the amplifying stage is stabilized within comparatively close limits. The most onerous conditions occur when the envelope of the incoming V.F. pulse has a comparatively slow rate of increment and decrement. Small changes in the value of the operate and release current of the relay may, under these conditions, produce intolerable distortion. Moreover, even if the circuit is adjusted to give a minimum distortion on a particular trunk line, it is difficult to maintain this condition over long periods of service, due to the changing characteristics of the valve itself.

One method of making the receiver less dependent upon the wave shape of the incoming signal is to apply rectified reaction to the relay operating stage. A typical arrangement is shown in Fig. 675. In the static condition (i.e. when no signal is applied) the bias on the control grid of the valve is adjusted so that the anode current is reduced to zero. The impressed signal is applied to the grid of the valve via the secondary of transformer $T2$, and this results in half-wave pulses of anode current just as in an ordinary anode-bend rectifier circuit. The pulsating anode current, in passing through transformer $T3$, induces an e.m.f. in the secondary circuit which is applied via rectifier *MRA* to the capacitor $C1$. The voltage built up on the capacitor is in such a direction as to decrease the static negative grid bias. This provides a fresh working point on the grid volts/anode current characteristic of the valve and, due to the higher mutual inductance at this point, the a.c. anode current is increased. The increased e.m.f. is now fed back to capacitor $C1$ so that the effective bias is still further reduced. This action is cumulative and continues until grid current commences to flow. The conducting condition of the control grid makes it impossible for capacitance $C1$ to attain a higher charge, so that the circuit stabilizes at this point. The circuit remains triggered in this manner, even when the input signal commences to decrease at the end of the impulse. At a certain point, however, the incoming signal will just be insufficient to sustain the circuit, and this allows the grid bias to increase slightly. The valve is now working on a less steep part of the characteristic so that the amount of a.c. feed-back to the grid circuit rapidly declines. A point is soon reached where the anode current is insufficient to maintain the relay in its operated condition.

The net result of including rectified reaction is to produce a rapid rise of the anode current from zero to a fixed maximum value within a very short period and at a rate which is not dependent upon the shape of the incoming signal envelope. Similarly, on release, the decrease of anode current is much more rapid than that which would be obtained due to the signal current alone. The resulting steeper waveform of the anode current makes the relay operate and release times less dependent upon slight variations in the mechanical adjustments, valve characteristics, etc.

An alternative arrangement, in which stability of operation is obtained by the use of a high speed relay, is illustrated in Fig. 676. The ordinary

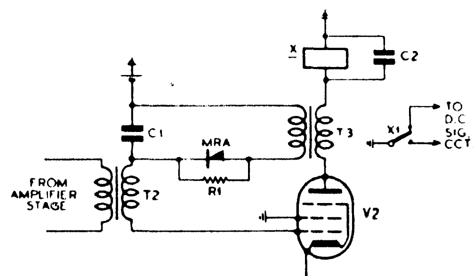


Fig. 675. Detector Circuit with Rectified Reaction

telephone type of relay has a high inductance (in order to get the necessary ampere-turns) and the value of the eddy currents is appreciable. As a result, the rise of flux in the relay lags behind the change of anode volts, and the net result is an

apparent flattening of the arrival and decay waveforms. This is largely responsible for the variations in impulse distortion which can result from slight changes in relay adjustment. A considerable improvement can be effected by the substitution of a relay which has a low inductance, small eddy currents and a consequent high speed of operation. The incoming signal (Fig. 676) is applied to a pair of rectifiers *MRA* and *MRB* which, in conjunction with capacitors *C*1 and *C*2, are arranged as a voltage doubling circuit. *R*1 is the load resistance, and the potential developed across this load resistance is applied to the grid of the pentode valve. This valve is normally biased so that the anode current is substantially zero, and the rectifier circuit is arranged so that the effective

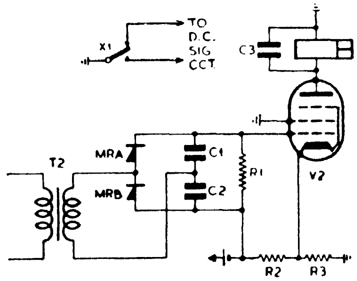


Fig. 676. Detection Stage with Rectified Signal and High Speed Anode Relay

bias on the grid is decreased on receipt of an incoming signal.

Fig. 677 is an interesting variation of the previous circuits in which the anode relay is made to behave in a double-current manner. The first control grid (*G*1) of the hexode valve is so biased that, under static conditions, a space current of, say, 3 mA flows between the cathode and the anode. This anode current operates the polarized relay (*X*) over its No. 1 coil. (The current through the second coil under these static conditions is negligible due to the potential gradient through the various grids and the higher potential of the anode.) An incoming V.F. signal is amplified in the usual way and is then passed via transformer *T*2 to a voltage doubler rectifier circuit comprising capacitors *C*1 and *C*2 and metal rectifiers *MRA* and *MRB*. This rectifier circuit is arranged so that the incidence of a signal decreases the positive potential applied to the second control grid (*G*3). This results in a decrease of anode current but a corresponding increase in the current via grid *G*2. (The total cathode current is largely determined by the potential on *G*1 and therefore remains substantially constant.) The net result is a reduction of the current in coil 1 but a current increase of similar magnitude in coil 2 of the relay. If the relay is designed so that its operate and

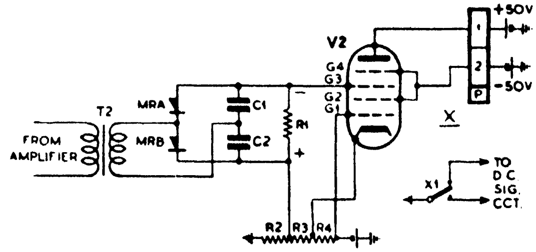


Fig. 677. Detection Stage with Hexode Valve and Two-coil Polarized Relay

release points are equally balanced about the zero current position, then its performance is largely independent of the magnitude of the incoming signal.

Another method of obtaining double-current effects is illustrated in Fig. 678. This circuit

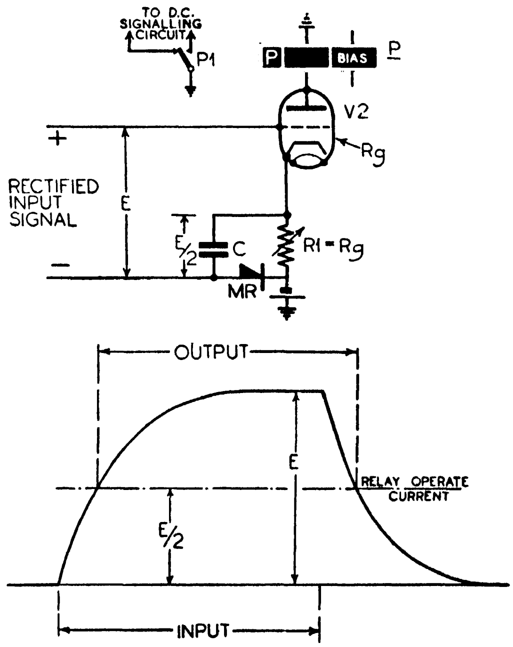


Fig. 678. Detection Stage with Automatic Bias Circuit to Produce Double-current Effects

utilizes a single-coil relay in conjunction with a simple triode valve, double-current effects being obtained by providing automatic grid bias equal to half the amplitude of the received signal. In the static condition, anode current flows and the

grid is biased due to the potential drop in resistor $R1$. The preceding rectifier network is arranged so that a positive potential is applied to the grid of the valve on receipt of an incoming signal. If the rectified signal voltage is E, and if the mutual resistance of the valve is Rg, then the increased voltage impressed on resistor $R1$ is given by

$$\left(\frac{R1}{R1 + Rg}\right) \times E$$

If, now, $R1$ is made equal to Rg, then the additional voltage impressed upon the cathode resistor is equal to $E/2$. The increase in voltage on resistor $R1$ causes capacitor C to charge in series with rectifier MR (in the conducting direction). When the signal ceases, the charge on C is prevented

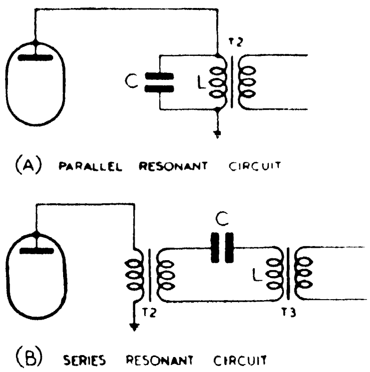


FIG. 679. SIMPLE PARALLEL AND SERIES RESONANT CIRCUITS

from leaking away by the high backward resistance of the metal rectifier MR. Thus, the bias of $E/2$ V is maintained on the grid of the valve during the period when there is no signal (provided that the interval between signals is not too long). By this means a bias of half signal amplitude is applied to the valve throughout the impulse train, the signals and the space between signals resulting in equal positive and negative variations from this mean value. It can be shown that, by a suitable selection of component values, it is possible to obtain distortionless impulse repetition over an amplitude range of some 6 db.

Selective Tuning of Receiver. The circuit elements so far considered have made no provision for differentiation between signals of different frequency. The receiving relay is therefore equally responsive to any voice-frequency signals which may be applied to it. It is desirable in practice to incorporate tuned or resonant circuits in the receiver to augment the available voltage at the signal frequency in order to provide discrimination against false operation by voice-frequency currents of other frequencies. The tuned circuits must be arranged to have "band-pass" characteristics, i.e. so that the signal frequency is passed forward to the detection stage whilst all other frequencies above and below the band are severely attenuated. The tuned circuits used in practice usually consist of a simple arrangement of capacitors and inductors to give elementary series or parallel resonant circuits. The upper portion of Fig. 679 shows a resonant combination in the anode circuit of the amplifying valve of the receiver. Capacitor C is placed in series with the primary winding of the coupling transformer $T2$, and the values are so adjusted that the capacitance and the inductance of the primary winding produce voltage resonance at the signal frequency. (Resonant frequency $f = 1/2\pi\sqrt{LC}$.)

The lower portion of the illustration shows an alternative arrangement in which capacitor C is placed in series with the primary winding of an additional transformer $T3$. (The additional transformer is, of course, necessary in order to maintain continuity of the d.c. anode circuit of $V1$.) The values of C and L are adjusted to produce series or current resonance at the signal frequency. The large resonant current values in the primary winding of $T3$ result in corresponding e.m.f.s in the secondary winding, which are applied to the detection stage of the receiver.

The characteristics of the tuned circuit have an important influence upon the shape of the signal passed forward to the detector stage. The best waveform (i.e. a waveform with steep arrival and decay curves) is obtained when the tuned circuit is comparatively flat. Such a circuit not only transmits the fundamental signal frequency but also allows a number of the components of the original waveform to pass without undue attenuation. We have seen in earlier paragraphs that a square-topped V.F. signal may be considered as a voice-frequency current modulated by a low-frequency-square-topped signal. The latter in turn can be considered as the fundamental impulse frequency plus a wide range of odd-numbered harmonics. As a result of this modulation, the received signal consists not only of the V.F. signal frequency, but also of a wide range of other frequencies produced as a result of the original modulation. It follows that, to reproduce a square-topped V.F. signal, the filter would require to have an infinitely wide band width, i.e. the filter must be omitted. On the other hand, a filter having a comparatively narrow band width and a high attenuation outside this band is very desirable

from the point of view of selective differentiation between the signal frequency and other unwanted currents. It can be shown that the time taken for the V.F. signal to reach a certain fraction of its maximum magnitude is inversely proportional to the effective band width of the filter (Fig. 680). The design of a filter must necessarily be a compromise between the two conflicting requirements of selectivity and good signal shape. Any a.c. signal, after passing through a filter, must of necessity be less steep than the waveform of the received signal (provided, as is usual, that the filter and not the line determines the range of frequency transmission).

Receiver Guard Circuits. Probably the greatest problem in the design of any system of voice-frequency signalling is to make the V.F. signalling circuit immune from possible false operation due to speech or any other extraneous currents on the line. This problem is particularly severe when the signalling system is superimposed on the normal speech path. Some degree of guarding against false operation by currents other than true signals is obtained by the tuned circuit in the receiver. This by itself does not provide sufficient safeguard against false operation, since the acceptance band of the V.F. receiver must be reasonably wide in order to produce satisfactory impulsing waveforms. Moreover, even if sharply tuned circuits were permissible, they do not guard against false operation due to speech components at the signal frequency.

Normal speech produces complex waveforms in which the component frequencies and their relative amplitudes are constantly changing. It is extremely improbable that the speech wave at any particular instant will contain the signal frequency alone (i.e. any transmission of the signal frequency by speech is almost invariably accompanied by the transmission of other frequencies). The chances are extremely small of a signal frequency component being of comparable level to the true signal whilst the remaining frequencies of the speech wave are of small magnitude. Apart from the presence of other frequencies, it is very rare for any one frequency to be maintained at reasonably high level for an appreciable period during normal speech.

The above factors make it possible to introduce devices in the V.F. receiver to reduce the possibilities of signal imitation by speech. In general, these guard circuits are arranged to:

(*a*) make the receiver unresponsive if a signal frequency current is accompanied by other frequencies, and

(*b*) delay the response of the receiver so that it will operate only if the signal frequency persists for a predetermined period.

The first method provides instantaneous protection and can therefore be used in all circumstances, even when (as in impulsing) accurate repetition of the signal period is required. The delay guard system produces time-distortion and cannot therefore be used during the reception of impulse trains, except where the delay is very short in comparison to the impulse period.

There is a number of methods of preventing a V.F. receiver from responding to the signal frequency if other frequencies are also present. The schemes are based on the provision in the V.F. receiver of two separate circuits. One of these responds to the signal frequency only, whilst the other is responsive to V.F. currents at other than the signal frequency. The latter is known as the *guard circuit*. The circuit arrangements are such that any voltage produced in the signal circuit tends to operate the receiver, whilst any voltage produced in the guard circuit tends to prevent the operation of the receiver. In effect, the receiver responds to the difference between the signal and guard circuit outputs. For purposes of analysis it is convenient to refer to the performance of the guard circuit by reference to the ratio of the outputs of the guard and signal circuits. Thus, if the voltage output of the guard circuit is X, and the voltage output of the signal circuit is Y,

$$\text{guard ratio} = X/Y$$

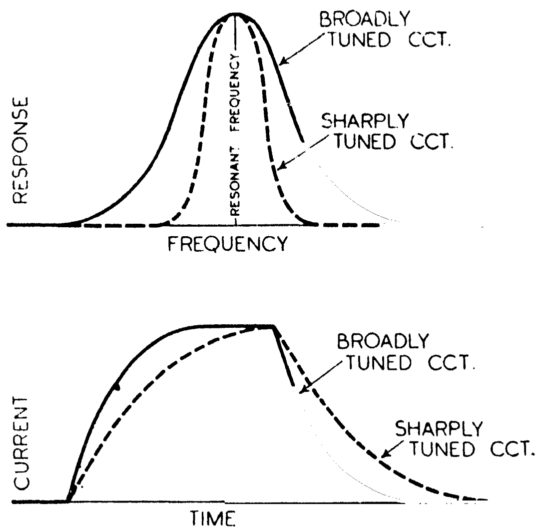


Fig. 680. Effect of Filter Band Width on Signal Shape

Tests carried out in recent years have indicated that signal imitation by speech is greatly reduced as the guard ratio is increased.

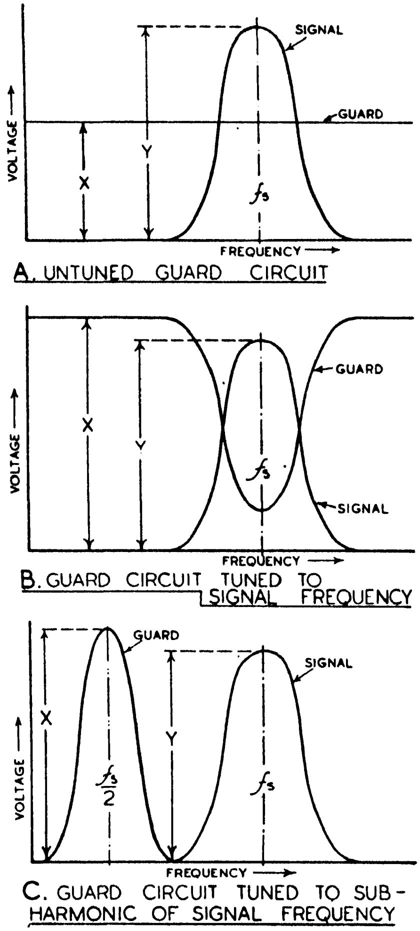


FIG. 681. ALTERNATIVE METHOD OF PROVIDING GUARD SIGNAL

Fig. 681 shows several alternative arrangements. At A the guard circuit is untuned and has an equal response over the whole frequency range (including the signal frequency). The signal circuit, on the other hand, is tuned to the signal frequency and has a peak response to a band of frequencies about that point. The effective voltage applied to the detection stage of the receiver is $Y - X$, and the guard ratio is X/Y. An alternative arrangement (shown at B) makes use of a guard circuit where the output is reduced over a narrow band with its centre at the signal frequency. As before, the effective voltage impressed on the receiver detection stage is $Y - X$ and the guard ratio is X/Y. The advantage of this arrangement is that a guard ratio greater than unity can readily be obtained with a consequent higher degree of immunity from signal imitation.

The lower portion of Fig. 681 shows a variation of the first scheme in which the guard circuit is tuned to give an increased response at the first sub-harmonic frequency of the signal frequency. This method has been used on a number of the existing V.F. receivers where signal frequencies of the order of 600–750 c/s are utilized. The first sub-harmonics (300–375 c/s) cover the normal range of the fundamental frequencies generated by the average human larynx and are also very responsive to the tones (and their first order harmonics) of automatic exchanges. This scheme is particularly useful in V.F. receivers which are designed to give severe voltage limitation at the first amplifier stage. Such voltage limitation produces amplitude distortion with the consequent generation of rich harmonics.

Figs. 682 and 683 indicate two alternative methods of providing the guard feature in a 2 V.F. receiver. In the first arrangement (Fig. 682) the guard circuit is tuned to a sub-harmonic of the signalling frequency. The d.c. potential obtained from the guard circuit ($E2$) is applied via resistor $R2$ between the suppressor grid and the cathode of the relay operating stage. The high impedance

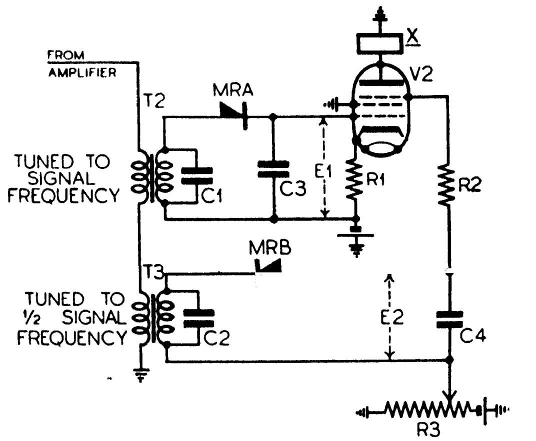


FIG. 682. TYPICAL GUARD CIRCUIT USING SUPPRESSOR GRID OF DETECTOR VALVE

load of the guard circuit makes it possible to obtain sufficient bias on the suppressor grid of the valve to provide complete cut-off of the anode current—irrespective of the signal potential on the control grid.

Fig. 683 shows an untuned guard circuit which

is arranged to provide a d.c. potential across a load resistor $R2$. The signal voltage is applied via the tuned circuit and a suitable rectifier to a separate load resistor $R1$. Resistors $R1$ and $R2$ are connected in series between the cathode and control grid of the detector valve. The voltage ($E2$) from the guard circuit developed across the load resistor $R2$ is in such a direction as to increase the negative bias on the control grid, whilst the signal voltage ($E1$) developed across $R1$ tends to reduce the negative bias on the grid. The decrease of grid potential is therefore dependent upon the difference in the voltages produced by the signal and guard circuits.

Signal Shaping. It has been seen that, in order to produce the minimum amount of impulse distortion, it is desirable that the arrival and decay wavefronts of an impulse signal should be as steep as possible. We have also noted that the final signal shape is largely determined by the characteristics of the band-pass filter. The comparatively narrow band width of the latter prevents the attainment of a sharp rise and decay of current in the relay circuit. There are various methods of steepening the growth and decay wavefronts of a signal. It is clear that any such shaping circuit must be located between the tuned circuit and the relay operating stage.

Fig. 684 shows a typical impulse shaping circuit in which the control is exercised by the guard

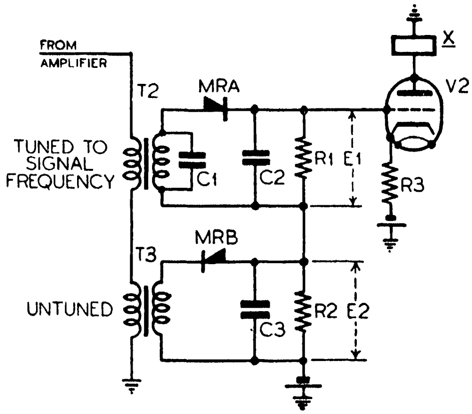


Fig. 683. Untuned Guard Circuit with Signal Applied to Control Grid of Detector Valve

circuit response characteristic. As the guard voltage builds up, capacitor $C1$ charges rapidly through the forward resistance of rectifier MRA, and hence there is a rapid build-up of potential across the load resistor $R2$. At the end of the impulse period, capacitor $C1$ discharges slowly through the high backward impedance of the rectifier and resistor $R1$. As a result, the guard voltage is maintained on the load resistor $R2$ (high

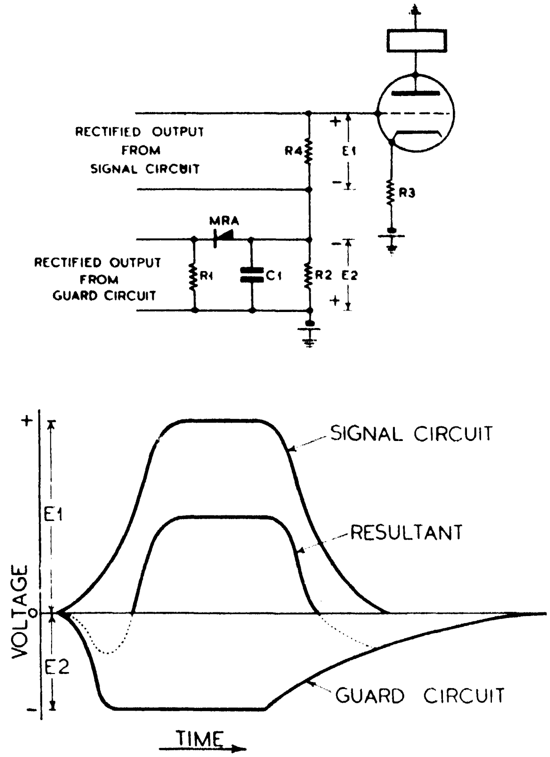


Fig. 684. Signal Shaping by Control of Guard Circuit Response Characteristics

resistance) after the cessation of the guard energization. The guard voltage is connected in opposition to the true signal voltage, and the effective signal is the difference between these two potentials. By suitably regulating the shape of the guard characteristic, it is possible to obtain a steep rise and a steep decline of the resultant voltage applied to the relay detection stage. The principle is shown diagrammatically in the lower part of Fig. 684. The reduction of the "hangover" time obtained by signal shaping tends to reduce the extent of signal imitation. Similarly, the rapid build-up of guard volts also helps to prevent false operation.

Signal Imitation. It has been stated that signal imitation by speech can be minimized by introducing a delay feature in the response of the V.F. receiver. Fig. 685 shows the results of some recent tests on trunk circuits carrying normal commercial speech (English). The susceptibility to signal imitation was observed for different signal frequencies and with receivers arranged to give

various delay guard periods. It will be noted that signal imitation by speech occurs most frequently when the signal frequency is of the order of 1000 c/s. As the signal frequency is increased, the number of signal imitations in unit time decreases rapidly. With a signal frequency of 1000 c/s, a guard ratio of 0·5 and a delay period of under 5 msec, upwards of 1000 false signals were received during one hour of normal speech. Under the

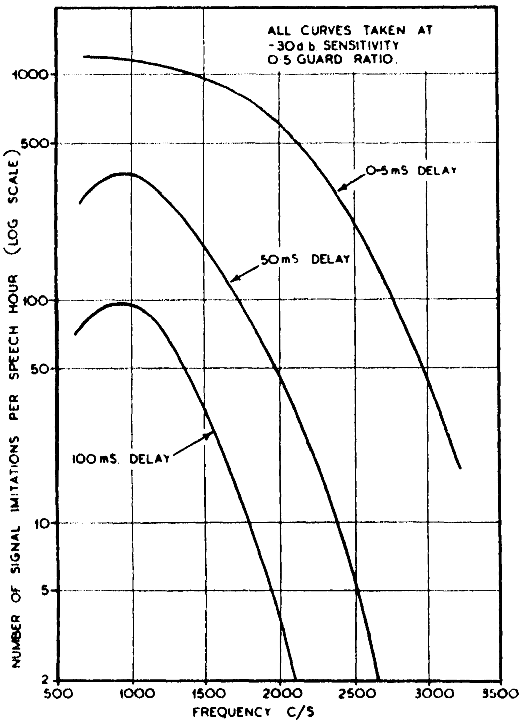


FIG. 685. EFFECT OF SIGNAL FREQUENCY AND DELAY TIME UPON SIGNAL IMITATION BY SPEECH

same conditions, but with a signal frequency of 3000 c/s, the number of such signal imitations falls to below 50 per hour. (Note that the vertical scale of Fig. 685 is plotted on a logarithmic basis.) As is to be expected, an increase in the delay time materially reduces the number of signal imitations. At a frequency of 2000 c/s, for example, only about 4 imitations per hour were observed as compared with some 600 imitations on circuits provided with a delay of 5 msec or less. These curves clearly illustrate the desirability (from a speech imitation point of view) of adopting a high signal frequency. From a practical point of view the frequency range 2000–2500 c/s appears to be a suitable choice. The curves also show that, wherever possible, it is of material advantage to introduce a time delay up to 100 msec.

It is possible to reduce still further the probability of signal imitation by the use of compound signals consisting of two or more frequencies. The use of such signals is considered later.

Signalling Codes. In a practical V.F. signalling system, a number of control signals are required. For example, a signal must be transmitted to the distant termination to seize the equipment and to prepare the circuits for impulsing. Further signals are required to indicate when the called party replies, and to give backward and forward clearing facilities at the end of the call.

Broadly speaking, the signalling systems used for control purposes may be classified either as *continuous tone* or *pulse code* systems. Continuous tone systems provide for the application (or cessation) of a continuous signalling tone for so long as a particular condition persists or until the next signalling condition occurs. For example, a V.F. system might possibly be arranged so that the seizure or calling condition could be indicated by the application of a continuous tone to line. The tone could be interrupted to provide the impulse trains, and the ultimate withdrawal of the tone at the end of the call would provide the necessary forward clearing signal. Similarly, the answering condition could consist of a continuous tone returned to the originating exchange until such time as the called party clears. This simple conception of continuous tone signalling is analogous to the conditions on a d.c. impulsing circuit where the normal seizure condition is a loop which is maintained until the end of the call, when the disconnexion of the loop provides the forward clearing signal.

If the V.F. signalling condition is superimposed on the speech path, it is clearly impossible to utilize any system which requires the transmission of tone during the conversational period. Even when a separate channel is used for signalling, there are technical and economic advantages in designing the signalling system so that the tones are transmitted only during the setting up and release of the call and not during the conversational time. Continuous tone signalling methods can, however, still be used by arranging that the answering signal is a disconnexion of a tone and by providing means whereby the calling signal is suppressed for the duration of the answering signal. The basic characteristic of all continuous tone signalling methods is that the appropriate conditions are maintained by the signals themselves.

A continuous tone signalling technique is not possible where the V.F. signals are superimposed

on speech circuits which are fitted with echo suppressors. Echo suppressors are sometimes fitted on long 4-wire audio circuits in order to prevent speech transmitted over the "go" pair from returning via the distant hybrid transformer and the associated "return" pair to the originating subscriber. Without echo suppressors such circulating currents may produce serious degradation of articulation efficiency or, if the transmission time is sufficiently long, may give a distinctive echo. The echo suppressor is inserted at a convenient point in the circuit, and is designed so that the transmission of speech in one direction automatically degrades the transmission efficiency of the associated pair, i.e. if speech is being transmitted on the "go" pair, the echo suppressor introduces a high attenuation on the "return" pair and vice versa. The presence of an echo suppressor on the speech circuit makes it impossible to transmit voice-frequency signalling tones in both directions concurrently since the energization of the suppressor due to a signal in one direction blocks the return signal path.

The use of echo suppressors necessitates the adoption of some form of pulse code signalling in which the various signals are either of short duration or are interrupted at frequent intervals to permit the de-energization of the suppressors, and hence to allow of the transmission of signals in the opposite direction. The seizure condition could, for example, be given by the transmission of a short pulse of tone which, when received at the distant termination, would set up the required conditions. Owing to the transient nature of the signal, locking circuits must be provided to maintain the required conditions until the next signalling pulse is received. Generally speaking, the circuit arrangements for a pulse code signalling system are much more complex than those of continuous tone systems. Not only must the various pulses be generated, but the receiving circuit must be capable of recognizing the various pulses from their duration or composition. The provision of locking circuits to convert from transient pulse signals to the "permanent" signals also adds to the complexity of the system.

Use of Two Signalling Frequencies. If the signalling system is restricted to the use of one frequency for all signalling purposes, the various signalling conditions can be recognized only by the length of the signal. For example, if a pulse signalling technique is adopted, and it is desired to provide seizure and forward release conditions from the outgoing end of a circuit, this would require signals of two different lengths in order that the equipment at the incoming termination could differentiate between the two conditions. These signals must, moreover, be readily distinguishable from the impulsing signals. The necessity for recognizing signals by reason of their length tends to complicate the design of the equipment at both ends of the circuit. Even with a fairly complex design it is difficult to obtain a large number of distinctive signals when the only difference between them is the time for which the signalling tone is applied.

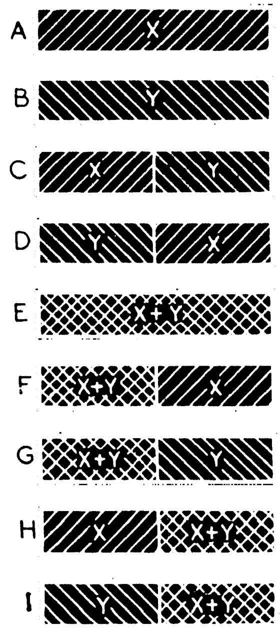


Fig. 686. Different Signals Obtainable by the Use of Two Frequencies
(All signals have same overall length)

The total number of possible signalling conditions is greatly increased by the use of signalling currents of two separate frequencies. This does, of course, require a somewhat more complicated V.F. receiver, and also means of generating the two frequencies at the outgoing end, but the advantages to be obtained from a system of two-frequency signalling may justify the additional cost, especially when a large number of different signals are to be provided.

When two such signalling frequencies are available, it is possible to provide a number of alternative and distinctive conditions without the necessity of introducing variable pulse duration for differentiation purposes. A selection of the more simple combinations available is given in Fig. 686. If the two frequencies are designated X and Y, two distinctive signals are obtainable by

the use of X and Y individually (A and B). By using one frequency as a prefix to the other frequency, two further combinations (C and D) are available whilst, by utilizing compound signals (consisting of both frequencies applied together),

DIGIT	CODE						
	25 mS.	25 mS.	25 mS.	25 mS.	25 mS.	25 mS.	25 mS.
1	Y		Y		Y		X
2	Y		Y		X		Y
3	Y		Y		X		X
4	Y		X		Y		Y
5	Y		X		Y		X
6	Y		X		X		Y
7	Y		X		X		X
8	X		Y		Y		Y
9	X		Y		Y		X
0	X		Y		X		Y

FIG. 687. POSSIBLE CODE SCHEME FOR THE TRANSMISSION OF NUMERICAL DIGITS

five further combinations (E to I) can be used. The total number of alternative conditions can be increased by the use of three or more unit signals, or by varying the length of the complete signal or of its component parts. The total number of signals available by the use of a two-frequency scheme is more than adequate to meet the normal requirements of a V.F. signalling circuit.

The use of a two-frequency signalling system has also some material advantages in minimizing signal imitation due to speech. If all other conditions are similar, a signal, consisting of, say, the X frequency followed by the Y frequency, is much less likely to be simulated by speech than any simple signal consisting of the X or Y frequency alone. The degree of immunity from speech imitation can be still further increased by the use of three-unit or other more complicated combinations of the two frequencies (e.g. X followed by Y followed by XY). Tests on actual working conditions have, however, revealed that an adequate degree of immunity from speech imitation can be obtained by the use of comparatively simple two-unit signals.

A two-frequency signalling system also opens up the possibility of utilizing coded signals instead of the normal impulse trains for the transmission of the numerical digits over a trunk line. A possible code scheme for the transmission of the digits 1 to 0 is shown in Fig. 687. With this arrangement each digit is represented by a particular combination of four short V.F. signals which are transmitted in rapid succession. The four pulses of signal current could, for example, be each of 25 msec duration and spaced at intervals of 25 msec, thereby providing for the transmission of a complete digit in a period of 175 msec. It will be noted that a four-unit code provides a number of spare combinations which can be used for any other purpose.

Apart from the saving in transmission time, the use of coded signals for the numerical digits has material advantages due to the elimination of the "impulse distortion" problem. Where Strowger impulses are transmitted over the trunk circuit, very great care must be taken in the design of the equipment to ensure that the impulses as repeated to the automatic equipment at the incoming end of the circuit are not distorted by more than a few milliseconds. With a coded signalling scheme, on the other hand, the actual duration of the component signals is not of great importance—provided that each component of the signal is of sufficient duration to operate the receiving relay. The main objection to the use of coded signals is the necessity for conversion equipment at both the outgoing and the incoming ends of the circuit to change over from the Strowger impulses to the coded signals along the trunk line. On the other hand, coded digit signals are of particular value on international circuits.

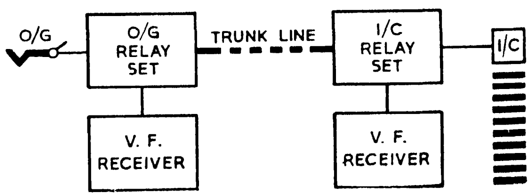


FIG. 688. GENERAL ARRANGEMENTS OF 2 V.F. DIALLING CIRCUIT

2 V.F. Dialling from Trunk Switchboards. The voice-frequency dialling system at present in use was designed primarily to permit zone centre operators to dial automatic subscribers at distant zone centres with automatic access to a limited number of other exchanges by interdialling through the zone centre automatic plant. The main signalling equipment (Fig. 688) is concentrated

into one relay set at each end of the trunk circuit. The outgoing relay set is directly accessible from the outgoing trunk multiple of the trunk exchange, whilst the incoming relay set is directly connected to a 1st selector. A V.F. receiver is associated with each terminal relay set, and the voice-frequency signalling currents are produced by inductor type tone generators (see Vol. I). The equipment is designed to permit of bothway or unidirectional working, as desired.

The signalling system is essentially a pulse code scheme utilizing two signalling frequencies of 600 and 750 c/s. For convenience the 750 c/s tone is referred to as the *X* tone, and the 600 c/s signal is known as the *Y* tone. The various signal pulses are generated in the terminal relay sets by means of uniselectors and slow-to-release relays.

Fig. 689 shows the system of signalling. When the originating trunk operator plugs into the multiple jack of the 2 V.F. circuit, a 100 msec pulse of *X* tone is transmitted to line as a seizure signal. This signal prepares the incoming relay set for the reception of impulses and provides for the seizure of the 1st selector. In director areas the incoming trunk selector gives access to A-digit selectors and thence to directors, so that the necessary translation can be obtained for the routing of the call to the appropriate exchange in the director area. It is important that the originating operator should not commence to dial before the A-digit hunter has found and seized a free A-digit selector. In order to guard against the possibilities of such premature dialling, arrangements are made to return a single "pip" of 900 c/s

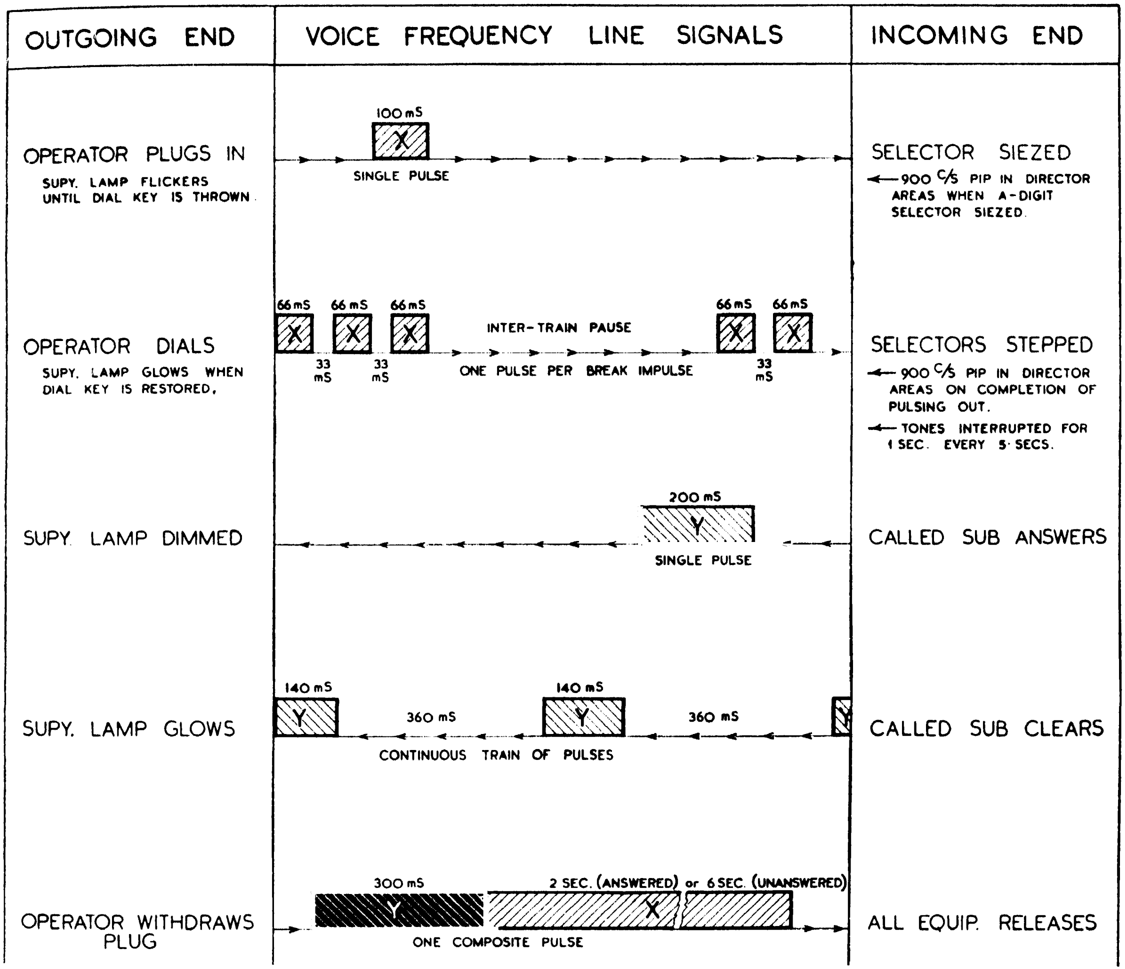


Fig. 689. Signalling System of British 2 V.F. Dialling Scheme

tone to the originating operator when an A-digit selector has been found. The usual flicker signal is given to the originating trunk operator when she plugs into an outgoing dialling circuit, and this signal continues until the dial key is thrown. The operator now dials the digits of the number required, and the break impulses are converted in the outgoing relay set to 66 msec pulses of X tone which are transmitted to line. These impulse signals are passed to the 2 V.F. receiver at the incoming termination where they are reconverted to normal direct current Strowger impulses. The impulses are passed via the incoming relay set to the 1st and subsequent selectors of the automatic switching train to set up the call in the usual manner. If the call is to a director area, a further single "pip" of 900 c/s tone is returned to the originating operator when the director has completed the re-transmission of the impulse trains. The normal supervisory tones (e.g. ringing, Number Unobtainable and busy tone) are returned from the automatic selectors over the trunk circuit to the originating operator who is therefore fully informed of the progress of the call. In order to prevent blocking of the forward signal path by echo suppressors, the circuit is arranged so that ringing and N.U. tones are interrupted for 1 sec every 5 sec. The cessation of the backward signal once every 5 sec de-energizes the echo suppressor so that signals can be transmitted from the originating exchange over the forward transmission pair. (This facility is essential in order that the originating operator can transmit a forward clearing signal if she encounters N.U. tone on a call.)

The originating exchange operator now restores her dial key, and the cord circuit supervisory lamp associated with the trunk circuit glows. In due course the called subscriber answers, and a single 200 msec pulse of Y tone is returned from the distant exchange to indicate the answering condition. This pulse is received in the outgoing relay set and provides for the dimming of the calling cord supervisory lamp. The answering pulse is made sufficiently long to give the receiver at the originating end of the circuit ample time to recover from shock excitation which might result from line surges which immediately precede the answering signal. The call is now established for conversation.

If the called subscriber clears first, a continuous series of Y pulses is returned to the originating exchange. Receipt of the Y pulse train at the originating exchange causes the calling cord supervisory lamp to glow, and the originating operator (after having verified that the call has finished) clears the connexion by withdrawing the calling plug from the multiple jack of the outgoing trunk circuit. This withdrawal of the plug causes a forward clearing signal to be transmitted to the distant equipment to release the train of selectors at the incoming termination. The forward clearing signal consists of a long pulse of X tone followed immediately by a somewhat shorter pulse of Y tone. This signal is designed so that the first (X tone) part of the signal is long enough to outlast any disturbance on the line and covers at least one break in the N.U. tone (if this should be encountered). In order to meet this latter condition, the X pulse is made of 5·5 sec duration if the call has been ineffective, i.e. if the answering signal has not been received. This period is, however, unnecessarily long on normal (answered) calls, and the circuit is arranged so that receipt of the answering signal is utilized to shorten the period to 1·5 sec. Receipt of the final part of the forward clearing pulse (the Y pulse) completes the release circuit for the incoming switching train. A two-part pulse is used for the forward clearing signal to provide a high degree of immunity from speech imitation. It has proved very effective in this respect.

Outgoing 2 V.F. Relay Set. Fig. 690 shows the detailed circuit arrangements of the outgoing relay set associated with a 2 V.F. dialling link. The circuit is designed so that it is accessible either from the trunk switchboard or from a selector level. If the circuit is seized from a manual board, the impulses from the operator's dial are repeated in the form of V.F. signals over the trunk circuit. Similar conditions exist if the circuit is seized over a selector level from a previous d.c. signalling link. If, on the other hand, the circuit is seized from a preceding 2 V.F. link, the X tone seizure signal is transmitted to line, and the circuit is then switched through to allow subsequent V.F. signals to pass without repetition.

Call from Manual Board. If the circuit is seized from the manual board, relay M operates over the sleeve circuit when the plug is inserted into the outgoing jack. ***M*1** operates relay MM. ***MM*3** applies flicker earth to the cord circuit supervisory lamp whilst ***MM*5** applies a busying earth to the incoming P-wire and operates relay RS. ***RS*1** in turn operates relay RD, and ***RS*4** energizes relay CO. ***RS*5** steps the uniselector under self-drive to contact No. 1. Relay CO changes over the line from the incoming relay set to the outgoing relay set if the circuit is worked on a bothway basis, and energizes the FLS relay. ***CO*7** releases relay RS.

The stepping of the uniselector from the home position to the first set of bank contacts provides a

holding circuit for relay *CO* (arc 1) and an operate circuit for relay *FXY* (arc 4). ***FXY*4** now connects "*X*" tone to line via transformer *TT*, backward transmission of the tone being prevented by the operation of contact ***FXY*2** which disconnects the anode circuit of the stopper valve (see later).

If the call is to a director area, the operator awaits receipt of the 900 c/s pulse from the trunk 1st code selector at the distant termination. No such signal is given in non-director areas, and the operator may proceed to dial immediately. The operation of the position dial key connects battery

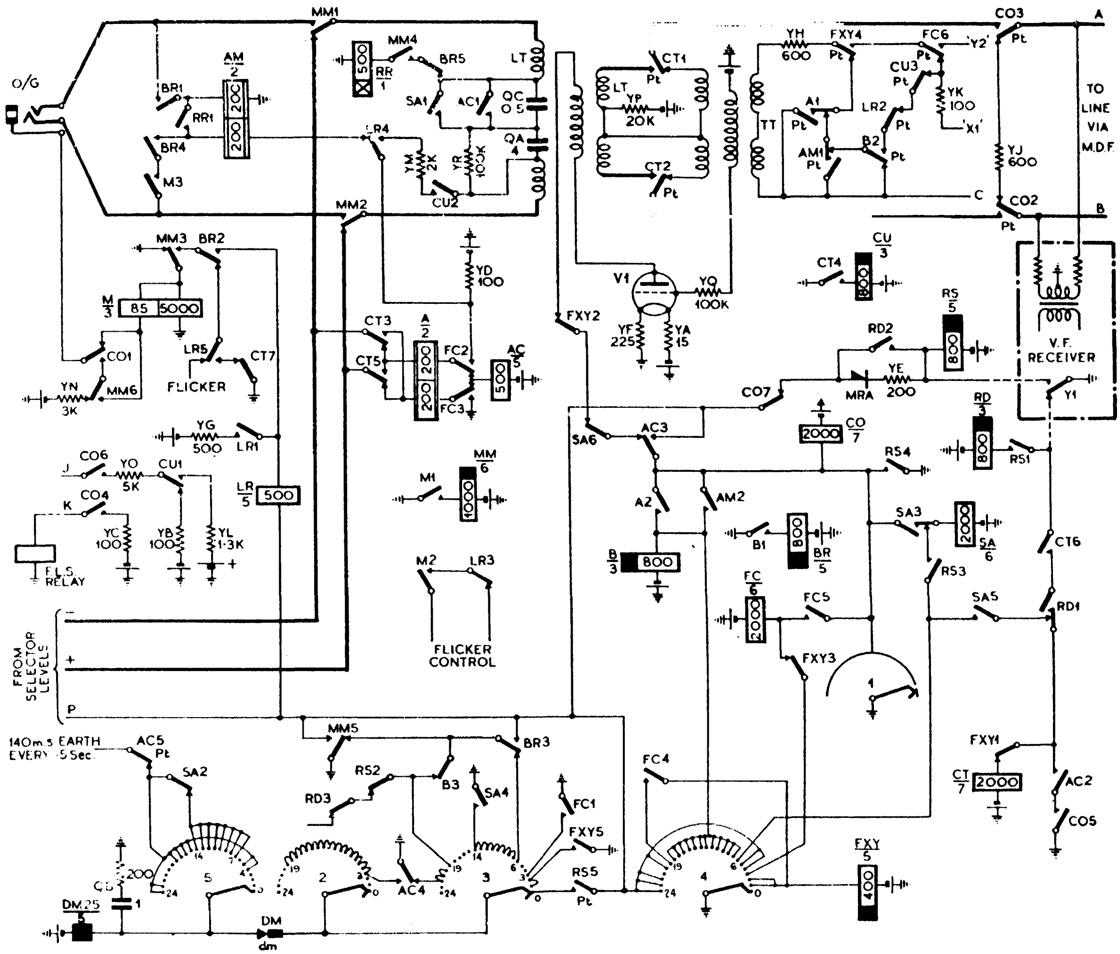


FIG. 690. CIRCUIT ARRANGEMENTS OF OUTGOING RELAY SET, 2 V.F. DIALLING

Contact ***FXY*5** steps the uniselector under self-drive from contact No. 1 to contact No. 3. When wiper No. 4 steps off contact No. 2, the holding circuit for relay *FXY* is broken, and this relay commences to release. After a period of some 70–100 msec, the contacts of relay *FXY* restore. *FXY*3 operates relay *FC*, whilst *FXY*4 disconnects the *X* tone from the line. Contact ***FC*1** steps the uniselector from contact 3 to contact 4 (via arc 3). The uniselector is now stepped to contact 6 under the control of ½ sec earth pulses via arc 5.

to the tip of the outgoing jack, thereby operating relay *RR*. ***RR*1** in turn operates *AM*, and ***AM*2** operates *B*. ***B*1** operates relay *BR*, and ***BR*1** and ***BR*4** connect the position dialling circuit to relay *AM*. ***BR*2** disconnects the flicker signal from the sleeve circuit and extends the latter to relay *LR*. *LR* does not, however, operate at this stage. ***BR*5** now disconnects relay *RR*, and after a period of lag (approximately 100 msec) *RR*1 restores to leave *AM* dependent upon the loop current from the dial circuit.

When the operator dials, AM releases during each break period of the dial impulse springs, and $AM1$ transmits X tone to line. On completion of dialling, the restoration of the dial key increases the value of the current in the sleeve circuit, thereby allowing relay LR to operate. $\boldsymbol{LR4}$ releases relay AM, and $AM2$ in turn releases relay B. $B1$ now releases BR, whilst $B2$ completes a circuit for the $600\,\Omega$ terminating impedance. When relay BR finally restores, $BR2$ connects earth to relay M to light the cord circuit supervisory lamp.

Up to this stage the speech conductors within the exchange are completely isolated from the line by contacts $CT1$ and $CT2$ (in order to prevent speech interference with the dialling signals). A path is, however, provided for the operator to receive incoming tone signals from the distant exchange during and after the setting up of the call. This unidirectional transmission circuit is provided by valve $V1$, the grid circuit of which is connected to one winding of transformer TT. Incoming tone signals produce an e.m.f. in the valve grid circuit. The resultant current changes in the anode circuit pass through a winding of transformer LT which repeats the amplified tone signals to the operator.

When the called subscriber answers, a 200 msec pulse of Y tone is received from the distant exchange. This operates relay Y in the 2 V.F. receiver, and $\mathbf{Y1}$ in turn operates relay RS. $\boldsymbol{RS3}$ operates relay SA, and $\boldsymbol{SA5}$ operates relay CT. Contacts $\boldsymbol{CT1}$ and $\boldsymbol{CT2}$ now switch the line through for speech, whilst $\boldsymbol{CT4}$ operates relay CU. $\boldsymbol{CT7}$ disconnects the shunting earth from the $5000\,\Omega$ winding of relay M to darken the supervisory lamp. Contact $\boldsymbol{CU2}$ connects battery to the ring conductor of the cord circuit to provide through signalling.

On the cessation of the Y pulse, relay RD operates during the slow release period of relay RS (approximately 150 msec). $\boldsymbol{RD1}$ makes relay CT dependent upon contact $Y1$, whilst the restoration of $RS1$ disconnects relay RD. After a release lag period of 375–400 msec $RD1$ restores and transfers the control of relay CT to the earth at contact 6 of uniselector arc 4.

The circuit is now established for conversation.

If the called party clears first, a continuous series of Y pulses is received from the distant exchange. The first operation of $\mathbf{Y1}$ (2 V.F. receiver) operates relay RS, and the first release of $Y1$ operates relay RD via $\boldsymbol{RS1}$. $\boldsymbol{RD1}$ now places relay CT dependent upon contact $Y1$ so that, at the commencement of the second Y pulse, $\mathbf{Y1}$ releases CT. $CT1$ and $CT2$ disconnect the speech circuit, $CT4$ releases relay CU, $CT7$ lights the cord circuit supervisory lamp, whilst $CT6$ prevents the re-operation of relay CT on subsequent releases of contact $Y1$. The restoration of $CU2$ disconnects the through signalling battery.

In due course the operator clears by withdrawing the calling plug from the outgoing jack. Relay M now releases, and $M1$ releases relay MM. $MM5$ removes the guarding earth from the P-wire, releases relay LR and steps the uniselector from contact 6 to contact 7. $MM6$ connects a temporary engaged condition to the bush of the outgoing jack. Relay B operates when wiper No. 4 steps to the 7th contact, and at $\mathbf{B1}$ operates relay BR which reconnects a guarding earth to the P-wire. $\mathbf{B2}$ connects X tone to line. The uniselector now steps from contact 7 to contact 15 under self-drive conditions to the earth at $\boldsymbol{SA4}$ (arc 3). It then steps from contact 15 to contact 19 under the control of the $\frac{1}{2}$ sec earth pulse applied via arc 5. During the stepping time of the uniselector from contact 7 to contact 19 (approximately 2 sec) relay B holds to the earth via arc 4 and maintains the transmission of X tone to line. Receipt of X tone at the distant termination cuts off the transmission of the backward clearing signal (Y pulses) thereby allowing relays RS and RD in the outgoing circuit to restore.

When the uniselector reaches contact 19, relay FXY is operated via arc 4, and at $\boldsymbol{FXY4}$ disconnects the X tone and connects Y tone to line. As the uniselector wipers step from contact 18 to contact 19, the circuit of relay B is broken, and after a period of lag the restoration of $B1$ releases relay BR, which at $BR1$ removes the guarding condition from the P-wire. $B3$ now steps the uniselector from contact 19 to contact 20, and a further drive circuit is provided from the earth at $AC4$ until the wipers reach contact 23. The guarding earth is again re-applied to the incoming P-wire at this stage from contact 23 of arc 4. As the wipers move from contact 19 the circuit of relay FXY is broken, and the restoration of this relay after a period of lag disconnects, at $FXY4$, the Y tone from the line. The circuit arrangements provide for the transmission of Y tone for a total period of approximately 250 msec.

The uniselector now steps to its home contact under the control of the $\frac{1}{2}$ sec pulse, and, when this contact is reached, relays CO, FC, and SA restore and the guarding earth is finally removed from the P-wire.

Call from Selector Level. When the outgoing V.F. circuit is seized from a selector level, the application of earth to the P-wire operates relay RS, and $\boldsymbol{RS1}$ operates relay RD whilst $\boldsymbol{RS4}$ operates relay CO. $\boldsymbol{RS5}$ extends the P-wire earth to step the

uniselector to contact 1. ***CO*1** applies the engaged test battery to the manual board multiple, whilst other contacts of the *CO* relay switch the circuit for an outgoing call and operate the *FLS* relay.

Relay *FXY* now operates to the earth at arc 4 as before, and at ***FXY*4** sends *X* tone to line. ***FXY*5** steps the uniselector, and as the wipers move off contact No. 2 the circuit of relay *FXY* is disconnected. *FXY*4 disconnects the *X* tone, whilst *FXY*3 operates relay *FC*. ***FC*1** steps the uniselector to contact 4, and the switch then steps to the ½ sec earth pulse until contact 6 is reached. ***FC*2** and ***FC*3** disconnect relay *AC* and connect relay *A* in readiness for impulsing. Relay *A* operates to the loop extended from the selector, and ***A*2** operates relay *B* to the earth at the homing arc of the uniselector. ***B*1** operates *BR*, and ***BR*3** applies a holding earth to the *P*-wire. During reception of the impulse trains relay *A* releases during each break period, and at *A*1 transmits *X* tone to line. At the completion of impulsing, ringing tone is returned to the caller through the stopper valve as previously described, and, when the called subscriber answers, a pulse of *Y* tone is received from the distant termination. The circuit operation is now substantially similar to that already described.

Call from Preceding V.F. Link. If the outgoing circuit is seized from a preceding 2 V.F. signalling link, balanced earth is extended over the — and + wires on seizure of the outgoing relay set. Under these conditions relay *AC* operates but relay *A* does not due to the differential action of its two windings. ***AC*4** steps the uniselector (under self-drive conditions) from contact 3 to contact 20 after the transmission of the *X* pulse seizure signal. The subsequent impulsing tones are transmitted straight through the outgoing relay set to the distant termination without repetition. At the end of the call the backward clearing signals are returned from the terminal exchange and are passed back (without repetition) over the preceding link to the originating exchange. These signals energize the *Y* relay in the intermediate V.F. receiver and, although relays *RS* and *RD* at the intermediate point are operated, the contacts of these relays are ineffective. When the originating operator clears, the transmission of the forward clearing signal causes the 2 V.F. relay sets at both the tandem and distant exchanges to clear down simultaneously.

Incoming 2 V.F. Relay Set. Fig. 691 shows the circuit arrangements of the relay set at the incoming end of a V.F. signalling trunk circuit. The relay set is designed to function in conjunction with a valve receiver which converts the 600 c/s and 750 c/s signalling tones on the trunk circuit into d.c. signals which are applied to the incoming selector train. Provision is also made for a "forward recall" signal on calls routed via the incoming trunk switchboard. The operation of the ringing key at the originating trunk exchange transmits *Y* tone over the trunk line, and this tone is converted to an earth signal over the + line of the automatic equipment to give the required recall facility.

We have seen that the seizure signal is a short pulse of *X* tone transmitted from the originating exchange. This causes the operation of relay *X* in the 2 V.F. receiver, and the changeover of contact ***X*1** operates relay *L*. ***L*1** operates *N*, whilst ***L*3** operates relay *LL*. ***L*4** provides a holding circuit for relay *L* in readiness for the release of *X*1. In non-director areas, ***L*5** operates relay *CL*, but in director areas *CL* is not operated at this stage, since it would prevent the transmission of the 900 c/s dialling signal from the trunk 1st code selector.

***LL*7** operates relay *PY*, ***N*1** operates relay *NR*, and ***CL*2** and ***CL*4** connect the line to transformer *TT*, the secondary of which is closed by a 500 Ω terminal impedance (*YF*). The contacts of relay *NR* now operate the free line signal associated with the outgoing portion of the circuit (if both-way) and also connect engaged test battery to the sleeve of the outgoing multiple. ***NR*3** engages the *P*-wire to prevent seizure from the selector levels.

At the end of the *X* tone seizure signal, the release of *X*1 completes a circuit for the operation of relays *NN*, *HS*, and *AR*. ***HS*1** completes the insertion of a 6 db stabilizing network formed by resistors *YA*, *YB*, *YC*, *YD*, and *YG*. This network is required to stabilize the line by preventing major changes in the terminal impedance as automatic switching progresses. The network also ensures that the tone input to the V.F. receiver is not shunted away if a momentary short circuit occurs during the routing of the call through the automatic equipment. ***AR*1** now completes the forward loop to seize the 1st selector.

The following relays are now operated: *L*, *LL*, *NN*, *AR*, *HS*, *N*, *NR*, *PY* (and *CL* in non-director areas). The originating operator can now proceed to dial (after awaiting the 900 c/s tone from the 1st trunk selector in director areas only). Each impulse consists of a 66 msec period of *X* tone followed by a 33 msec period of no tone. Relay *X* of the 2 V.F. receiver responds to these impulses. At the commencement of the first impulse, ***X*1** disconnects the circuits of relays *HS* and *AR* and operates relays *P* and *C*. *HS*1 disconnects the transmission path to prevent the surges on the selector side of transformer *LT* during the first

release of *AR*1 from being returned over the trunk line. Relay *AR* releases slightly behind relay *HS* due to the effect of capacitor *QC*. *AR*1 disconnects the loop to the selectors, thereby repeating the signal as a loop-disconnect impulse to the 1st selector. Relay *C* operates shortly after the release of *AR*, and at **C5** excludes the *D* relay from the forward impulsing loop during subsequent terminates the disconnect-impulse to the 1st selector. This cycle of operations continues during each successive impulse of the train, contact *AR*1 repeating the impulses to the 1st selector as already described. During the interdigit pause relay *C* releases, but relays *HS* and *AR* are held. *HS*1 maintains the transmission path for the return of supervisory tones to the originating operator,

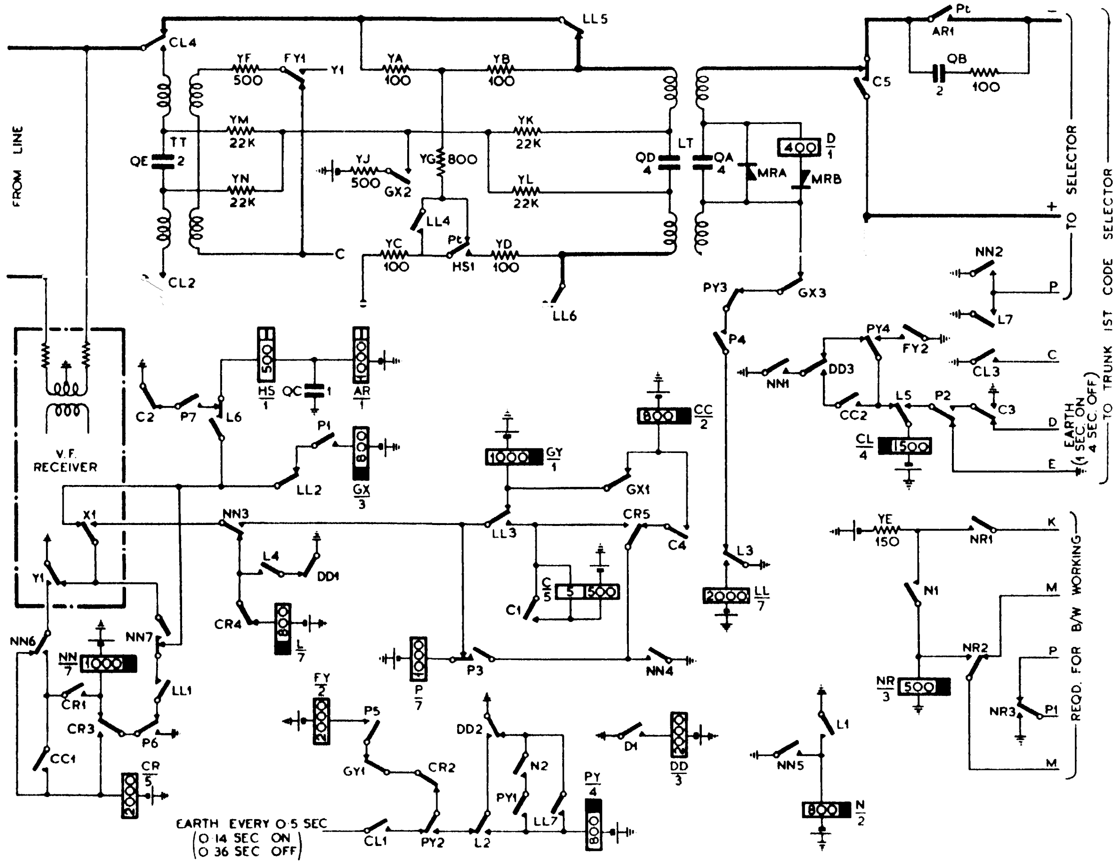


FIG. 691. CIRCUIT OF INCOMING RELAY SET, 2 V.F. DIALLING SCHEME

impulses of the train. In director areas contact **C3** operates relay *CL* to provide the necessary 500 Ω terminating impedance (*YF*) during impulsing. **C4** operates relays *CC* and *GY* from the earth at ***NN*4**, but these relays have no function at this stage.

Relay *X* of the 2 V.F. receiver releases at the termination of the first impulse, and at *X*1 re-operates relays *HS* and *AR*. At the same time *X*1 disconnects the operating circuit of relay *C*, but this relay holds during the time between impulses due to its short-circuited 5 Ω winding. ***AR*1** whilst ***AR*1** holds the selector train. *C*3 disconnects the holding earth from relay *CL* and connects this relay to the 5 sec earth pulse supply. *CL* therefore operates for 1 sec every 5 sec, and at **CL2**, ***CL*4** interrupts the tones. (It has already been shown that this is necessary to prevent blocking of the signal path by the operation of the echo suppressors to continuous tone.) *C*4 breaks the holding circuit for relays *CC* and *GY*.

The above cycle of operations is repeated for each succeeding digit, and, when the call has been completely established, ringing tone is returned to

the originating exchange if the required line is free. (This tone is interrupted for 1 sec every 5 sec by relay *CL* as described above.) The following relays are now operated: *L*, *LL*, *NN*, *AR*, *HS*, *N*, *NR*, *PY*, *P* and *CL* (the latter pulsing to the 5 sec earth).

When the called subscriber answers, relay *D* operates due to the reversal of the loop current, and at ***D*1** operates relay *DD*. ***DD*1** releases relay *L*. *L*2 disconnects the holding circuit of relay *PY* and operates relay *FY* via ***PY*2** during the release lag period of *PY*. *L*3 releases *LL*, and *L*5 disconnects the *CL* relay from the 5 sec earth supply (*CL* holds to the earth at ***FY*2** until *PY* restores). *L*6 transfers the holding circuits of relays *HS* and *AR* to the control of contacts *C*2 and ***P*7**. *LL*4, *LL*5, and *LL*6 remove the 6 db stabilizing impedance from the speech circuit.

The operation of relay *FY* connects (at ***FY*1**) *Y* tone to line via transformer *TT*. (It will be noted that the *Y* tone returned to the originating exchange also operates relay *Y* in the local V.F. receiver circuit, but contact ***Y*1** has no effect.) *PY* releases after a period of lag, and at *PY*2 releases relay *FY*. *PY*4 disconnects the holding circuit of relay *CL*. *FY* in releasing disconnects the *Y* tone from the trunk line, whilst *CL*2 and *CL*4 disconnect the tone transformer *TT* and complete the speech transmission circuit. The disconnexion of the *Y* tone allows relay *Y* in the local V.F. receiver to restore, and at *Y*1 a circuit is completed for the operation of relay *GX*. ***GX*1** guards relay *CC* against false operation should relay *X* be energized as a result of speech currents. ***GX*2** connects a small direct current to the contacts in the transmission path to provide the usual wetting condition. The circuit is now established for conversation with the following relays energized: *N*, *NR*, *HS*, *AR*, *NN*, *P*, *D*, *DD*, and *GX*.

When the called party clears relay *D* releases, and at *D*1 releases relay *DD*. *DD*3 now operates relay *CL*, and ***CL*1** connects the ½ sec earth pulse to relay *FY*, thereby causing the latter to operate for approximately 140 msec during each period of 500 msec. Contacts ***CL*2** and ***CL*4** disconnect the speech transmission path and reconnect the tone transformer *TT*. *FY* operates to the earth pulses, and at ***FY*1** connects *Y* tone to line (via transformer *TT*) for periods of 140 msec every 500 msec. This train of *Y* pulses continues until the operator at the originating exchange clears. If the called party lifts his receiver during this period, relays *D* and *DD* re-operate and the consequent release of *CL* and *FY* stops the backward clearing signal.

At the conclusion of the call, the originating operator withdraws the plug from the outgoing multiple jack, and thereby initiates the forward clearing signal. This signal consists of a 2 sec period of *X* tone followed by a 250 msec period of *Y* tone. Relay *X* in the incoming 2 V.F. receiver responds to the 2 sec of *X* tone. ***X*1** releases relay *GX* and operates relay *GY*. ***GY*1** disconnects relay *FY*, thereby stopping the transmission of the backward clearing signal. ***GX*1** operates relay *CC*. At the expiry of the *X* pulse, relay *X* releases and relay *Y* operates to the following pulse of *Y* tone. *X*1 releases *GY* and *CC*, whilst ***Y*1** operates relay *CR* (via ***NN*6** and ***CC*1**). ***CR*5** operates relay *C*, and ***C*2** in turn releases relays *HS* and *AR*. *AR*1 breaks the holding loop to the local selector train. *CC*1 disconnects the holding circuit for relay *NN*.

At the expiry of the forward clearing signal, relay *Y* in the 2 V.F. receiver restores, and at *Y*1 releases *NN* and operates relay *GX*. *NN*1 in turn releases *CL*, *NN*4 releases relays *P* and *C*, whilst *NN*5 releases relay *N*. *P*1 releases *GX*, whilst *P*6 releases *CR*. *CL*2 and *CL*4 now restore the line to normal whilst *N*1 releases relay *NR*. The restoration of *NR* removes the engaged condition from the *FLS* circuit, from the multiple jacks, etc. All relays are now restored and the circuit is free for further traffic.

If the call is ineffective (i.e. if the called subscriber does not reply) the outgoing relay set at the originating exchange transmits a clearing signal consisting of approximately 6 sec of *X* tone followed by 250 msec of *Y* tone. This ensures that the clearing signal reaches the terminal exchange even although the forward signal path may be blocked by the operation of echo suppressors during the 360 msec period for which backward supervisory tones are transmitted. If busy tone is encountered during the setting up of a call, relay *D* does not operate and the 6 db stabilizing attenuator remains in circuit. In other respects the release of the circuit is exactly the same as that described above.

Relay *GY* provides the guard delay to avoid irregular operation by speech currents. This relay is operated during the conversational period, and any fortuitous operation of relay *X* in the local V.F. receiver must be of longer duration than the release lag of *GX* for it to be effective, i.e. before it initiates the release cycle by the operation of relay *CC*. A further safeguard is provided by relay *GY*, which is arranged to stop the transmission of *Y* pulses (the backward clearing signal) whenever relay *X* in the local receiver operates. Without this feature there is a possibility that the forward

clearing signal might be imitated by a false pulse of X tone followed by one of the Y pulses.

Diode Stabilized 2 V.F. Receiver. Fig. 692 shows the complete circuit of a 2 V.F. receiver designed for use with the current standard signalling frequencies of 600 c/s (Y tone) and 750 c/s (X tone). The input signal is applied to a voltage limiting stage ($V1$) which is based on the principle already illustrated in Fig. 673. The output of this voltage limiter is applied to 600 c/s and 750 c/s tuned circuits and thence to the control grids of two detector valves ($V2$ and $V3$). The detection stages employ rectified reaction (see Fig. 675). The guard circuit consists of two circuits ($T3$ and $T4$) which are tuned to the first sub-harmonics of the signal frequencies, i.e. to 300 c/s and 375 c/s. The output of the guard circuit is applied to the suppressor grids of the detector valves $V2$ and $V3$ in such a manner that the valves are inoperative (irrespective of the presence of signal frequencies) if the guard circuit is energized. A double-diode valve ($V4$) is connected between the amplifier and detector stages, and is arranged as a voltage limiter to stabilize the performance of the receiver as the valve characteristics change with age (and as the characteristics of other components change with temperature). (See Fig. 674.)

The input terminals are connected via 2 KΩ resistors to the primary winding of the input transformer $T1$. These series resistors increase the input impedance of the receiver, thereby minimizing the transmission loss resulting from the permanent connexion of the receiver across the trunk circuit. With the arrangement shown, the bridging loss does not exceed 0·25 db over the range 300–3000 c/s (it is considerably less than this at mid-frequencies). The input transformer has a step up voltage ratio 1 : 10, and the secondary of this transformer is connected to the grid of the first stage ($V1$). A 0·01 μF capacitor shunted by a 5 MΩ resistor is included in this grid circuit. Under the static condition the grid is at the same potential as the cathode of the valve but, when an a.c. signal is applied to the grid, the latter becomes positive with respect to cathode during each alternate half-cycle. During these positive periods there is an electron flow from the grid to the cathode which produces a charge on the 0·01 μF capacitor. The polarity of this charge produces a negative bias on the grid of the valve. An input signal of large amplitude produces a large negative grid bias voltage, and a signal of smaller amplitude produces a relatively small bias. The valve is therefore automatically biased by an amount which is related to the amplitude of the signal voltage. The instantaneous grid voltage

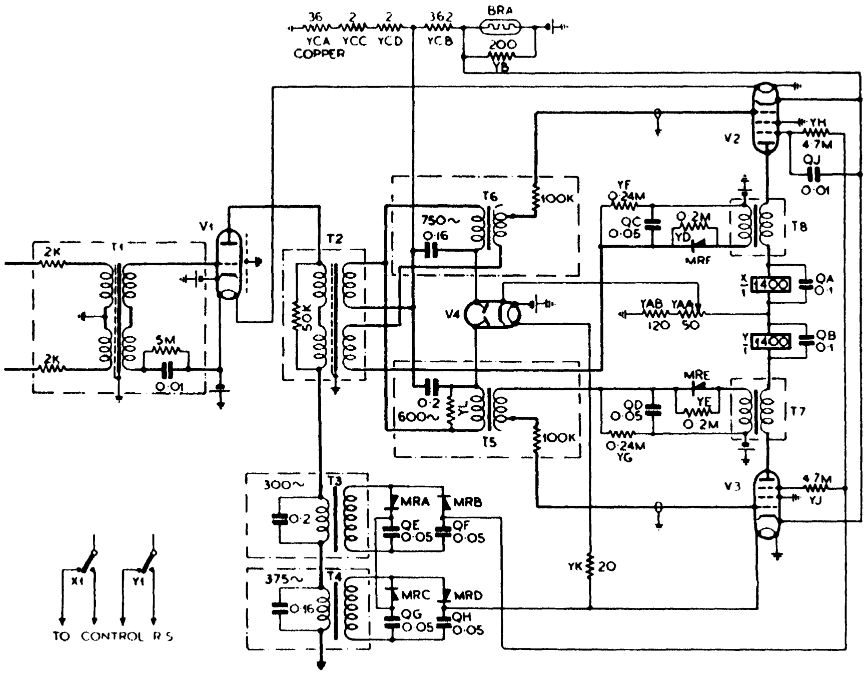


FIG. 692. 2 V.F. RECEIVER WITH DIODE VALVE STABILIZER

during receipt of a signal is equal to the difference between the negative bias and the signal voltage, and hence the maximum resultant positive voltage remains reasonably constant over a fairly wide range of input level. In this receiver the components have been so selected that, with an input level range of from − 12 db to + 10 db (into 600 Ω impedance), the pulses of anode current have a substantially constant value. The 5 MΩ resistor is, of course, necessary in order to prevent a "hangover" of the biasing condition at the termination of the signal.

The anode circuit of the voltage limiting valve is connected to the primary windings of three transformers *T*2, *T*3, and *T*4 which are connected in series. The secondary winding of *T*2 is connected to two further transformers *T*5 and *T*6 which are tuned to the signal frequencies by the 0·16 μF (750 c/s) and the 0·2 μF (600 c/s) capacitors. Transformer *T*2 has a 66 : 1 step-down ratio in order to match the impedance of the tuned transformers to the preceding amplifier valve. The secondary windings of transformers *T*5 and *T*6 are connected via 100 KΩ resistors to the control grids of the detector valves *V*2 and *V*3. When a signal of one of the resonant frequencies is received, a high voltage is developed across the secondary of the transformers and hence to the control grids of the detector valves. The secondary winding of *T*6 is connected in series with an additional winding of *T*2 to preserve a flat waveform when *X* signals (750 c/s) of high amplitude are being received. This refinement is not required for the *Y* frequency circuit since this frequency is not used for impulsing and a much greater degree of time distortion can be tolerated.

The relay operating stages (*V*2 and *V*3) employ the rectified reaction principle. The static grid bias is adjusted to a value of approximately 7 V negative, whilst the screen is given a potential of approximately 43 V positive with respect to the cathode. The anode has a similar static potential. In the absence of a signal the anode current is very small and is insufficient to operate the relay. When a signal is received the positive half-cycles applied to the grid cause pulses of current to flow in the anode circuit. These pulses pass through the anode transformer (*T*7 or *T*8), thereby inducing an alternating voltage in the secondary circuit. The voltage induced in the secondary of the anode transformer is rectified by *MRE* or *MRF* and is applied to capacitor *QD* or *QC*. The direction of the resultant charge is such as to reduce the normal negative bias of the grid. This in turn increases the amplitude of the anode current pulses. Thus, if the input signal is greater than a certain critical minimum value, the anode current rapidly builds up to the operate value of the anode relay. (The action is known as "triggering" the valve.) When the input signal ceases, the a.c. component in the anode current is no longer present and the charge on capacitor *QC* (or *QD*) leaks away through resistor *YF* (or *YG*). This causes the anode current to decrease until a point is reached when the anode relay restores.

Valve *V*4 is introduced to stabilize the level of the signals applied to the rectified reaction stages by limiting the voltages applied to the tuned circuits. In order to prevent the diode from affecting the initial rise in the amplitude of the signal, the bias voltage is obtained from the anode circuit of the detector valves. The component valves are so adjusted that voltage limitation due to the diodes does not take place until the detector valve is "triggered."

The guard circuit consists of the two transformers *T*3 and *T*4 which, as stated earlier, are tuned to the first sub-harmonics of the signal frequencies. The secondary windings of these transformers are connected to voltage doubler rectifier networks. The resultant d.c. potentials are connected in series and are applied via 4·7 MΩ resistors to the suppressor grids of the detector valves. During normal operation to a signal frequency the suppressor grid is at approximately the same potential as the cathode, but if sub-harmonic-frequencies are present at the same time a large negative bias, sufficient to cut off the anode current, is produced on the suppressor grid. The tuning of transformers *T*3 and *T*4 is comparatively flat so that protection against false operation over a band width of approximately 250–400 c/s is obtained.

A ballast resistor (*BRE*) is included in the circuit to compensate for variations in the exchange battery voltage. Resistor *YCA* is wound of copper so that its value increases with rise of temperature. This is introduced to increase the bias voltage on the diode valve to compensate for the effects of temperature variations on the characteristics of other components in the circuit.

The *X* and *Y* relays used in the 2 V.F. receiver are of the standard 3000 type design but with somewhat close adjustment limits. A receiver in correct adjustment will respond satisfactorily over a 24 db range of input, and introduce a maximum distortion of about 1 per cent between these limits. The receiver will respond to a frequency variation of ± 20 c/s, and within this range the distortion is kept to within 2 per cent. It will respond to impulse frequencies of from 7–12 I.P.S. with a maximum distortion of some 1 per cent. The overall impulse distortion of the receiver under

normal working conditions ranges from about — 4 to + 3 per cent.

Limitations of Original 2 V.F. System. It has been stated earlier in this chapter that the 2 V.F. system described in the preceding paragraphs was designed primarily to permit trunk operators to policy of the Post Office to provide automatic switching of trunk calls wherever possible. Although all zone centre exchanges have direct circuits to all other zone centres, it is still necessary to establish a considerable number of trunk calls via two or more links in tandem.

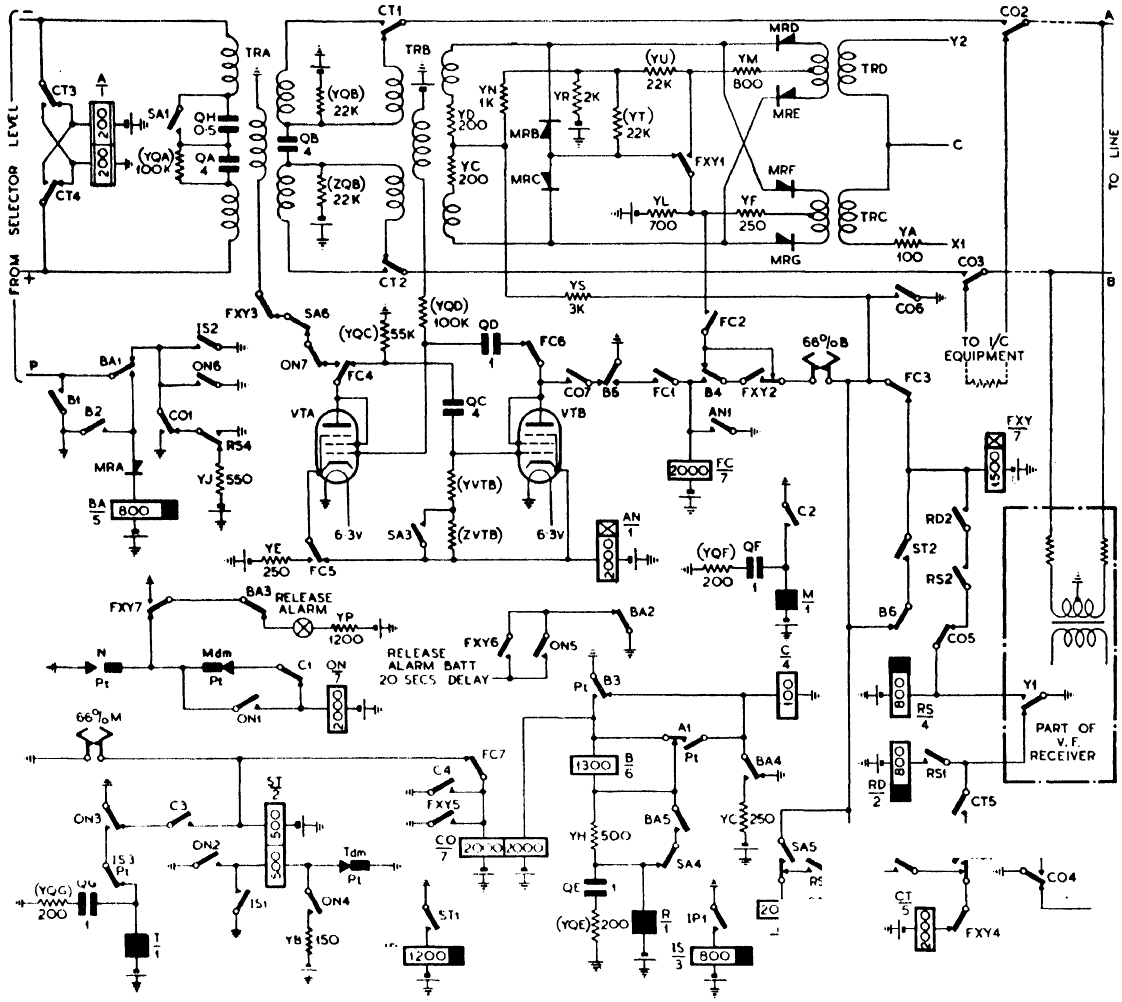


FIG. 693. OUTGOING 2 V.F. CIRCUIT WITH REGENERATOR

dial automatic subscribers over direct circuits to distant zone centres. At the time of its introduction the long-distance circuits were normally provided on a "demand" basis (see Vol. I). When the trunk circuits are provided on such a basis, there are difficulties in arranging for extensive tandem dialling throughout the trunk network. During recent years the number of long-distance trunk circuits has been greatly increased, and it is now standard practice to provide all long-distance circuits on a "no delay" basis. It is also the

The present 2 V.F. system has certain limitations which render it unsuitable for use in an automatic trunk switching scheme with extensive tandem dialling facilities. The first difficulty is due to the comparatively long seizure time of a 2 V.F. link. Under the existing signalling system, the following sequence of operations must take place before the incoming selector at the distant termination is ready to receive impulses:

(*a*) The d.c. seizure signal must be converted in the outgoing relay set into a V.F. pulse.

(*b*) The V.F. seizure pulse (100–150 msec pulse of X tone) is transmitted to line under the control of a stepping uniselector and a slow-to-release relay.

(*c*) At the incoming termination the V.F. pulse must be converted into a d.c. seizure signal, and this signal must be applied to the incoming selector.

(*d*) The A and B relays of the incoming selector must operate on receipt of the seizure signal.

If the circuit is accessible from the level of a trunk selector, the latter must first hunt for a free outgoing trunk circuit, and the above sequence of operations must take place before the incoming selector is prepared for the reception of impulse trains. The total period involved exceeds the time available during the normal interdigit pause from the originating operator's dial. There is therefore a danger of premature impulsing with the present system of signalling over 2 V.F. links.

The original 2 V.F. system also produces a degree of impulse distortion which may be intolerable under tandem dialling conditions. In general it is possible to have one d.c. signalling link subsequent to the V.F. circuit, but difficulties are anticipated if the V.F. link is preceded by other V.F. or d.c. impulsing circuits. The main cause of impulse distortion on the V.F. link is due to the comparatively poor impulsing performance of the relay used for the initial repetition in the outgoing relay set.

The power consumption of the 2 V.F. receiver is comparatively high, and any large extension of the V.F. dialling scheme with the present equipment would introduce a number of difficult problems concerned with the supply of power to the receivers. This aspect is particularly important when consideration is being given to the extension of 2 V.F. dialling to the smaller group centre exchanges.

Outgoing Relay Set with Regenerator. Fig. 693 gives the circuit details of a proposed new outgoing 2 V.F. relay set. This circuit provides substantially the same facilities as the relay set illustrated in Fig. 690, but is more suitable for tandem dialling via the levels of automatic selectors. The distinguishing feature of the circuit is the inclusion of an impulse regenerator, the outgoing impulse trains of which control the V.F. line signals via a "static" relay. These two features very materially reduce the amount of impulse distortion and provide an adequate margin of safety during the interdigit pause when the V.F. link is seized from a selector level. It will also be noted that the new circuit does not include a uniselector. The shorter V.F. pulse signals are controlled by relay timing, whilst the long forward clearing signal is timed by an electronic circuit of the "flip-flop" type.

The static relay has been in use for some years on V.F. telegraph systems. The application of this principle to 2 V.F. telephone circuits is shown in Fig. 694. The static relay, in essence, consists of four rectifiers *MRA*, *MRB*, *MRC*, and *MRD* which can be biased as required to provide a high

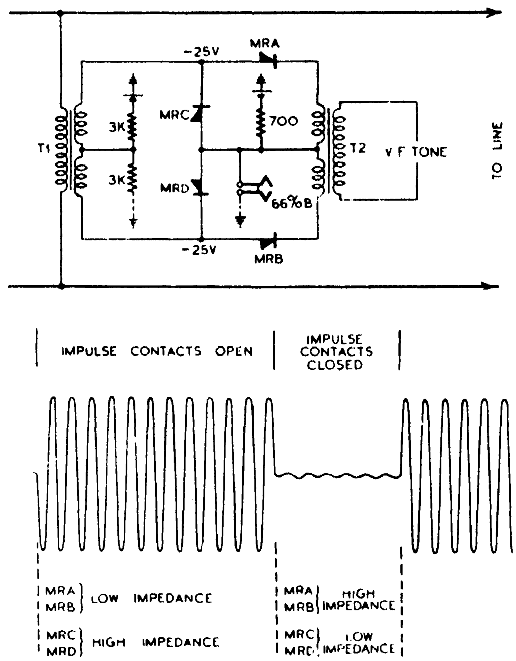


FIG. 694. STATIC RELAY CONTROL OF SIGNAL TRANSMISSION

or low attenuation in the transmission path of the V.F. tone signals. In the simplified element of Fig. 694 the circuit is arranged to transmit tone to line when the dial impulsing contacts are open (i.e. during the break impulse period). In the static condition (with the impulsing contacts closed), the centre-point of transformer $T2$ is at earth potential. The centre-point of transformer $T1$ is given a potential of approximately -25 V from the potential divider formed by the 3000 Ω resistors. Under these conditions rectifiers *MRC* and *MRD* are biased in such a direction that they have a low impedance, and, since these rectifiers are connected across the tone circuit, they provide a very heavy *shunt* loss. Rectifiers *MRA* and *MRB* are biased in such a direction that each rectifier offers a very high impedance. These rectifiers are connected in series with the tone

supply, thereby providing a very high series impedance. The combined effect of both groups of rectifiers is a very high attenuation of the tone signal transmitted to line.

When the regenerator impulse contacts open, the potential at the centre-point of transformer *T*2 is changed from earth to —50 V. This circuit change reverses the polarity of the bias on all the rectifiers thereby producing minimum series and minimum shunt losses. A high value of tone is thus transmitted to line during the open period of the impulsing contacts. The lower part of Fig. 694 shows the effect on the amplitude of the tone

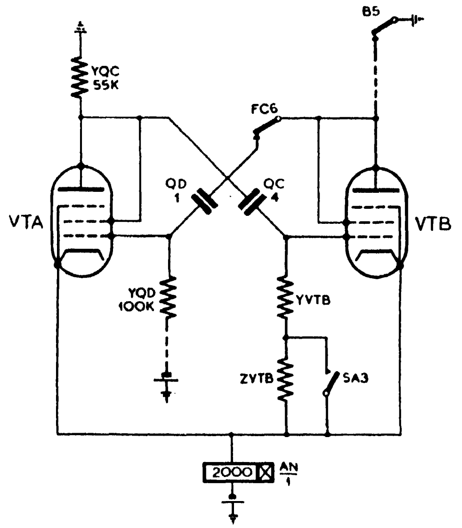


FIG. 695. PRINCIPLE OF "FLIP-FLOP" VALVE TIMING CIRCUIT

to line resulting from the switching of the bias by the impulsing contacts. In the more detailed circuits provision must be made for the transmission of *X* tone or of *Y* tone in accordance with the required 2 V.F. signals, and various relay contacts are introduced to control the static relay during seizure, supervisory, etc., conditions.

Fig. 695 shows the electronic timing circuit which controls the duration of the long *X* pulse which must be transmitted to line during forward clearing. The timing circuit is started by the release of contact *FC*6 which completes the charging circuit of the 1 μF capacitor *QD*. The build-up of potential across resistor *YQD* resulting from this current drives the grid of *VTA* more positive, and a small anode current flows in this valve. The current is, however, insufficient to operate relay *AN*. As the anode current in *VTA* rises, the potential drop across the 55 K anode resistor *YQC* causes capacitor *QC* to discharge. ***The discharge current, in passing through*** resistors *YVTB* and *ZVTB*, drives the grid of *VTB* negative, thereby cutting off the anode current. Relay *AN* remains normal until the current in the *VTB* grid resistors falls to such a value that the anode current in *VTB* commences to rise. The timing circuit is controlled by a contact of relay *AN* (not shown). The time delay introduced by this circuit can readily be varied by adjusting the value of the *VTB* grid resistors (*YVTB* and *ZVTB*). We have seen in earlier paragraphs that two lengths of *X* pulse are required during the forward clearing signal, i.e. a 2 sec pulse of *X* tone on effective calls, or a 6 sec pulse of *X* tone on calls which have not been answered. These different timing intervals are obtained by contact *SA*3 which short-circuits part of the grid resistor of *VTB*. In the complete circuit *VTA* is also used as the normal stopper valve to isolate the exchange equipment from the line until the answering condition is received.

When the outgoing 2 V.F. circuit (Fig. 693) is seized from a selector level, relays *A*, *B*, *BA*, *CO*, *FXY*, *ST*, *IS*, and *IP* operate in sequence. ***CO*6** applies earth to the static relay to start the transmission of the *X* tone seizure signal and also operates relay *FC*. ***FC*3** disconnects *FXY* and the restoration of *FXY*2 reverses the bias of the rectifiers to terminate the transmission of *X* tone. The period of this initial signal (about 100 msec) is determined by the operate lags of *FXY* and *FC*, and the release lag of *FXY*. The incoming impulse trains are repeated by contact *A*1 to the receiving magnet of the mechanical impulse regenerator, and at the end of each impulse train relay *C* releases to "mark" the appropriate pin (see Chapter VI). At the correct time the regenerator commences to discharge the stored digits, and during each open period of the impulsing contacts the static relay is biased in such a direction that *X* tone is transmitted to line for a 66 msec period during each impulse. An intertrain pause of from 700–1200 msec is provided by the release lags of relays *ST*, *IP*, and *IS* in sequence.

When the called subscriber answers, a 200 msec pulse of *Y* tone is received from the distant termination. This operates relay *Y* in the V.F. receiver at the outgoing end of the circuit. ***Y*1** operates relay *RS* and ***RS*3** operates relay *SA*. Contact ***SA*6** disconnects the anode circuit of the stopper valve, whilst ***SA*2** operates relay *CT*. Contacts ***CT*1** and ***CT*2** now switch the call through for conversation. (At the end of the *Y* pulse relay *RS* releases, and in so doing operates relay *RD* whilst contact ***RS*1** is closed. These relays are not effective at this stage.)

If the calling subscriber clears first, relays *A* and

B release and *B*5 releases *FC*. *B*6 completes a circuit for relay *FXY*. Contact *FC*2 in releasing removes earth from the static relay to send *X* tone to line. *FC*4 and *FC*5 disconnect the anode and cathode of *VTA* from the stopper valve circuit and complete the connexions for the electronic timing circuit. *FC*6 completes this timing circuit. *FXY*4 releases *CT* and *CT*1 and *CT*2 establish the signalling circuit via transformer *TRB*. After a delay period of approximately 2 sec (assuming that the call has been answered), relay *AN* operates to the rising anode current in *VTB* and at ***AN1*** re-operates *FC*. ***FC2*** and ***FXY1*** now bias the static relay so that *Y* tone is transmitted. The operation of ***FC7*** releases relay *ST*. The *Y* tone operates relay *Y* in the local V.F. receiver, and ***Y1*** in turn operates *RS*. The opening of contact *ST*1 releases *IP*, whilst *ST*2 releases relay *FXY*. Contacts *FXY*1 and *FXY*2 now cease the transmission of *Y* tone to line. *FXY*5 releases relay *CO*.

If the called subscriber clears first, *Y* tone at 0·5 sec intervals is received from the distant termination. The first operation of contact **Y1** in the outgoing V.F. receiver operates relay *RS*, and at the termination of the *Y* pulse the restoration of *Y*1 operates *RD*. The second operation of **Y1** releases *CT* so that contacts *CT*1 and *CT*2 change over from speech to signalling conditions. *CT*5 in restoring prevents the re-operation of *CT* on subsequent releases of the *Y*1 contact.

If the call is unanswered, relay *SA* is not operated, and the inclusion of resistor *ZVTB* in the grid circuit of *VTB* increases the timing period from 2 to 6 sec.

In some circumstances the forward clearing signal might be ineffective due to the signalling path being blocked by the echo suppressors as a result of speech in the reverse direction from the called party. Pulses of *Y* tone are received from the distant termination when the called party replaces his receiver. The first operation of contact ***Y1*** energizes relay *RS*, and at the end of this first pulse *RD* is operated via *Y*1 and ***RS*1**. *RD* holds until the next operation of **Y1**. A circuit is now completed for relay *FXY* via ***RS2*** and ***RD2*** during the release lag of relay *RD*. Contact ***FXY5*** operates relay *CO* which in turn holds relay *FXY* at contact ***CO6***. After a delay period of 6 sec the circuit clears down in the normal way.

The complete circuit includes facilities (not shown in Fig. 693) for busying the outgoing relay set from the incoming termination of a 2 V.F. link. If the incoming circuit is so busied, $\frac{1}{2}$ sec pulses of *Y* tone are reverted to the outgoing end of the circuit and the latter, on receiving these pulses, transmits the forward clearing signal (2 sec *X* tone followed by 800 msec *Y* tone). Approximately 50 msec after the end of the *Y* tone the incoming relay set returns a 500 msec pulse of *Y* tone which operates contact **Y1** in the receiver of the outgoing termination. This occurs with relays *IS* and *RD* operated and with relay *CO* normal. Under these conditions the earth from **Y1** is used to artificially engage the outgoing 2 V.F. circuit on the selector multiple. The busying condition is released by the transmission of $\frac{1}{2}$ sec *Y* pulses from the incoming termination, thereby setting up repeat clearing conditions in the outgoing relay set.

Provision is made to give an alarm in the event of a failure of the time delay circuit. Such a failure is indicated if relay *FC* fails to operate after the timing interval. Since relay *FC* releases *FXY* (at *FC*3) the failure of *FXY* to release is utilized as the fault condition. Contacts ***FXY7*** and *BA*3 complete the release alarm lamp circuit. ***FXY6*** and *BA*2 extend earth to the delayed alarm circuit, whilst ***FXY5*** holds relay *CO* to maintain the engaged condition at ***CO*1**.

New 2 V.F. Receiver Circuit. Fig. 696 shows the circuit arrangements of a new 2 V.F. receiver which has recently been developed. The main objects of the new design are

(*a*) to minimize the impulse distortion, and
(*b*) to provide a receiver of lower energy consumption than earlier designs.

The line is terminated on an input transformer *T*1, the secondary of which is connected to the control grid of valve *V*1. The latter is arranged as a straight amplifier and, since it is of high impedance, it behaves substantially as a "constant current" source to transformers *T*2, *T*3, and *T*4 in the anode circuit. The receiver is designed to operate over a range of incoming signal levels of from + 10 to − 24 db. No special voltage limiting arrangements are provided in the first amplifier stage, but there is in practice a certain measure of limiting action due to overload of the valve when the signal input exceeds about − 5 db. This particular receiver is designed for use with signal frequencies of 600 c/s and 750 c/s, and the secondary windings of transformers *T*4 and *T*3 are tuned (by capacitors *C*2 and *C*1) to these frequencies. The incoming signal is converted to a d.c. condition by the rectifiers and capacitors which are connected as a voltage doubler circuit in order to increase the potential available to the next stage. The d.c. signal voltage resulting from a 600 c/s input is applied across the load resistor *R*1, whilst *R*2 provides the load resistance for the 750 c/s circuit.

A guard circuit (to minimize signal imitation by speech) is provided by transformer $T2$ and the full-wave rectifier bridge. This guard circuit is untuned, i.e. it responds equally over the complete frequency range. The d.c. voltage produced by the guard circuit is impressed across the guard load resistor $R3$ which is connected in series with the signal load resistors $R1$ and $R2$. The values so biased that, in the idle condition, a space current of approximately 3 milliamps flows through the No. 1 coil of the polarized relays in the anode circuit. The value of this total cathode current is largely determined by the bias on control grid No. 1, and remains substantially independent of change of potential on control grid No. 2. When, due to the receipt of a signal fre-

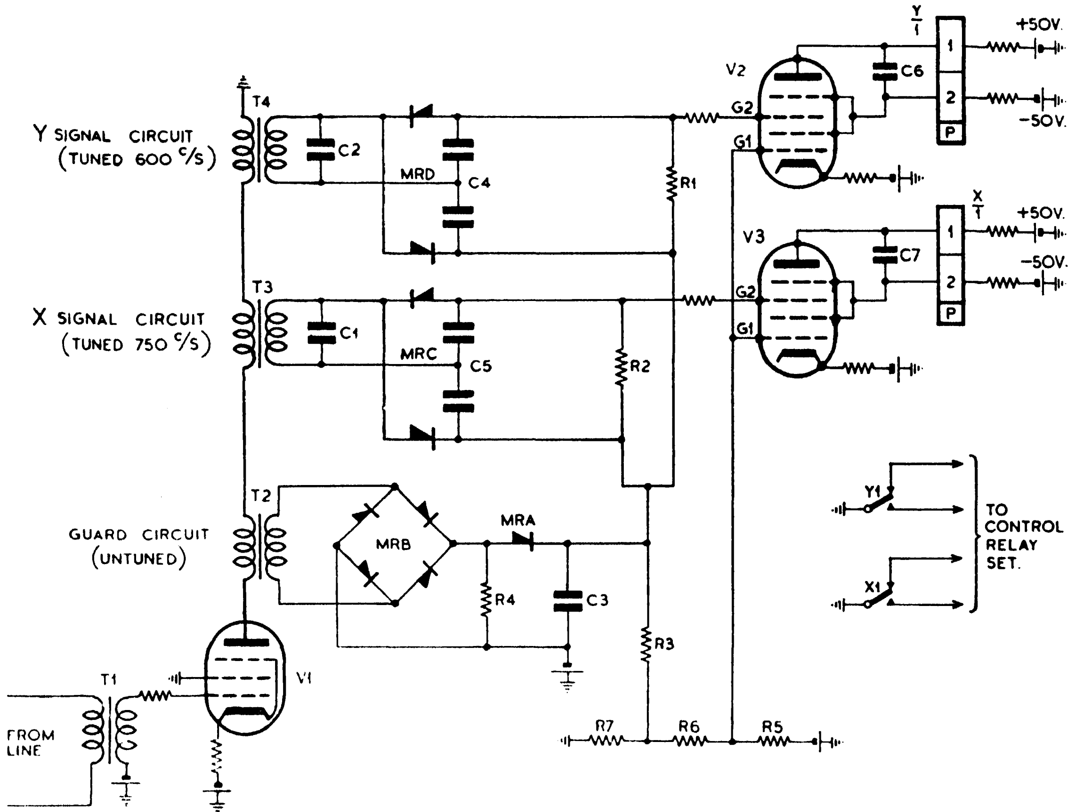


FIG. 696. LOW CONSUMPTION 2 V.F. RECEIVER WITH UNTUNED GUARD CIRCUIT AND TWO-COIL POLARIZED ANODE RELAYS

are adjusted so that, on receipt of a true signal (say, 600 c/s), the voltage developed across the guard resistor ($R3$) is equal to half the voltage generated across the signal load resistor $R1$. Similarly, on receipt of a 750 c/s signal, the voltage developed across $R2$ is equal to twice the voltage developed across $R3$. The voltages across the guard signal load resistors are opposite in direction, so that the effective potential applied to the control grid of the second stage valves is half the voltage developed in the signal circuit. The guard ratio (q.v.) of the receiver is therefore 0·5.

The detection stage of the receiver consists of two hexode valves ($V2$ and $V3$). The valves are

quency, the volts across the signal load resistor exceed the voltage developed across the guard resistor, control grid No. 2 becomes more negative and the space current is diverted from the anode circuit and coil No. 1 of the relay to the lower grid and thence to coil No. 2 of the anode relay. The relay is designed to change over almost immediately the signal volts exceed the guard volts, so that they operate more or less at the half signal level, i.e. substantially distortionless repetition is obtained.

Resistors $R5$ and $R6$ are arranged as a potential divider in order to obtain the correct voltages on the control grids of $V2$ and $V3$. $C6$ and $C7$ are

smoothing capacitors across the impulsing relays and are introduced to prevent relay chatter during operation. Some degree of signal shaping is obtained by the network $R4$, MRA, and $C3$ in the guard circuit. This device has already been illustrated in Fig. 684 and has the effect of steepening the effective waveform of the signal applied to the detection valves, thereby reducing impulse distortion and signal imitation.

The valves used in this receiver are fitted with 6·3 V heaters, and the total anode consumption is approximately 5 W. It will be noted that a 50 V positive battery is required in addition to the usual 50 V exchange battery.

Separate Signalling 2 V.F. Systems. The adoption of signalling by voice-frequency currents on the normal speech transmission path presents certain inherent problems. In the first place, the signal receiving equipment must be made immune from false operation by speech which, as we have seen, involves the provision of more or less complex frequency discrimination equipment, and the introduction of time delays in the signalling circuit to prevent false operation due to momentary applications of the signalling frequency. The fact that the signalling currents are within the voice-frequency range also necessitates the adoption of pulse signalling technique, which again complicates the circuit terminations. Difficulties are also liable to arise from the operation of echo suppressors which, on very long lines, must be provided to meet transmission requirements.

These three major difficulties of a 2 V.F. signalling system could be avoided if a scheme could be devised whereby all signalling were carried out on a channel which is completely divorced from the normal speech circuit. Such a scheme could use a continuous tone signalling system which would obviate the need for pulse type seizure, answering and release signals. There would be no question of signal imitation by speech, and there would, of course, be no need for echo suppressors on the signalling channels. Moreover, if the signalling channels were arranged on a 4-wire basis, i.e. separate go and return signalling paths, signals could be transmitted in both directions at the same time (i.e. duplex signalling). The use of continuous signalling tone makes possible rapid seizure of a circuit. This is particularly important in tandem working where the seizure of a circuit and certain selector hunting must take place during the interdigital pause.

Against these advantages the cost of the additional signalling channel must be taken into account. It is, of course, not necessary to have a channel of the same band width as that required for speech transmission, and hence one speech channel could be divided into a number of signalling channels, each of comparatively narrow band width. (For example, a speech channel with a frequency band width of from 300 to 3400 c/s could be made to cater for 20 separate voice-frequency signalling channels, i.e. it could serve 20 trunk circuits.) Nevertheless, the circuit used for signalling purposes cannot be used for speech, and its cost must be included in the total cost of the signalling equipment. Moreover, if one channel is used to provide signalling on a number of separate circuits, it is necessary to provide a reserve circuit, and possibly automatic changeover equipment in order to guard against a major breakdown. The cost of the reserve circuits and changeover equipment must also be included.

The principle of having separate channels for signalling and for speech may complicate the tracing of faults and may introduce service difficulties. For example, it may be possible to set up a call on the signalling circuit and to obtain all the appropriate supervisory signals, but the corresponding speech channel may be out of order.

The separate signalling and speech circuits must be brought together at each termination. Any through signalling must, therefore, be translated to d.c. signalling at each tandem point and then reconverted to V.F. signalling for the next link. This difficulty of providing continuous end-to-end signalling without repetition is a major disadvantage of the separate channel scheme.

General Arrangements of Separate Signalling System. Fig. 697 shows in block schematic form the general arrangements of a separate signalling 2 V.F. system. Two channels (a "go" and a "return") are set aside for signalling, and each channel is divided into 21 sub-channels of 100 c/s band width. The lowest channel occupies the 300–400 c/s band, whilst the last channel occupies the 2300–2400 c/s band. The signalling frequencies are generated by separate oscillators, the signalling frequencies being odd harmonics of a fundamental 50 c/s wave. Thus the lowest signalling frequency is the 7th harmonic (350 c/s), and the signalling frequencies for the remaining channels are 450, 550, 650, etc., to 2350 c/s which caters for the band 2300–2400 c/s. Of the 21 signalling channels, 20 are used for the signalling paths of 20 separate trunk circuits, and the 21st signalling channel is reserved for alarm purposes. The band 800–900 c/s is reserved as the alarm circuit, and a 850 c/s tone is continuously transmitted along this sub-channel. If the transmission equivalent of the signalling channel drops beyond 3 db (or if the tone ceases) a fault is assumed, and all the signalling circuits

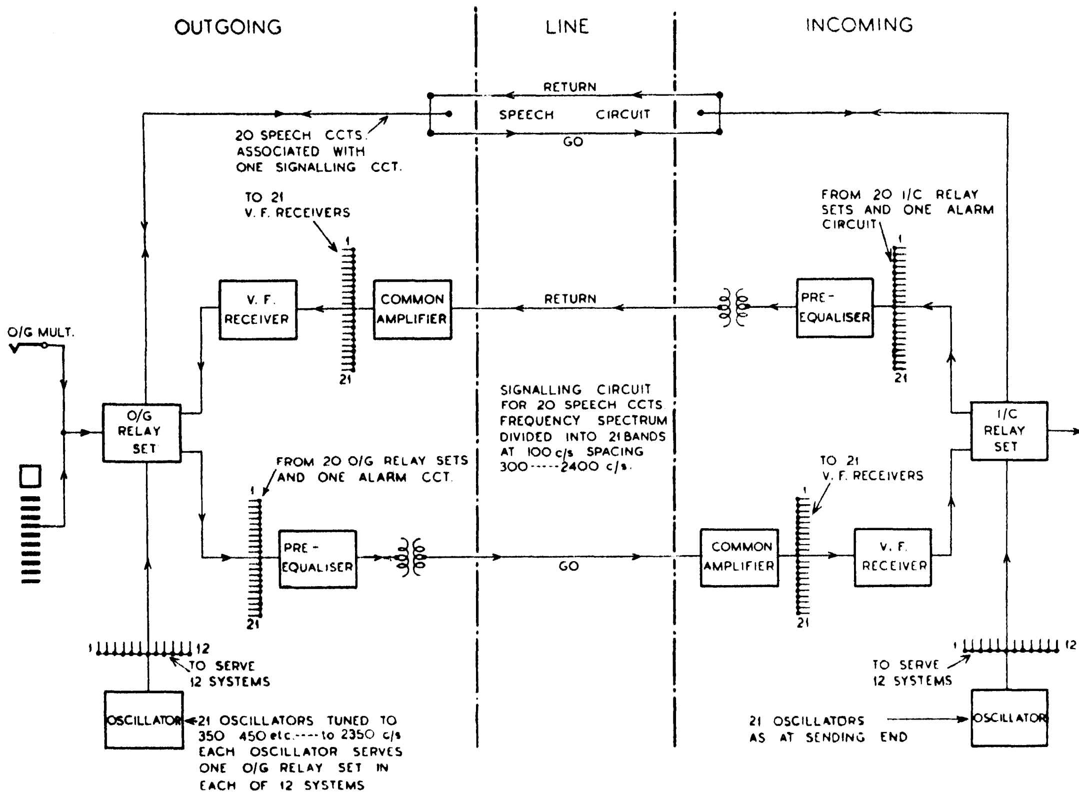


FIG. 697. SCHEMATIC DIAGRAM OF SEPARATE SIGNALLING SYSTEM

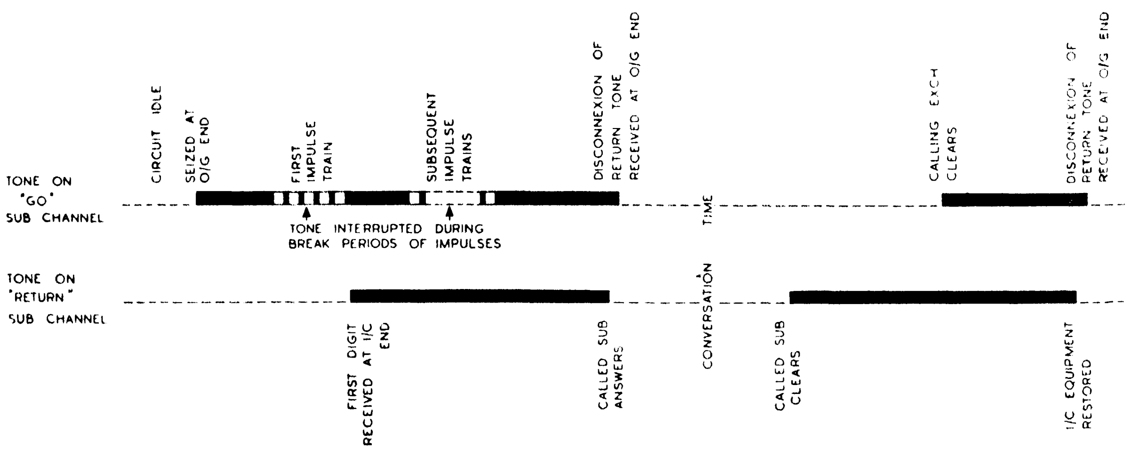


FIG. 698. SIGNALLING SCHEME (SEPARATE SIGNALLING SYSTEM)

are switched to a reserve circuit. The 850 c/s tone alarm frequency is chosen to be as near as possible to the normal lining up frequency of 800 c/s.

The system is designed to operate with pulses of down to 20 msec duration, i.e. the system will respond to a pulse transmission speed of 50 bauds.

Signalling Code. Fig. 698 shows the signalling code. When the circuit is seized from the outgoing end, a continuous tone is applied to line to seize the distant exchange equipment. The impulse trains consist of 66 msec interruptions in the tone with the normal interdigital pause between impulse trains. When the first digit has been received at the incoming end, tone is applied to the return signalling channel, and continues until such time as the called subscriber answers. The tone returned from the incoming end now ceases, and the cessation of this tone at the outgoing end stops the transmission of the initial tone on the go channel. When the called subscriber clears, the supervisory tone is re-applied at the incoming end of the circuit and continues until the incoming equipment is fully released after the receipt of a forward clear from the originating end of the circuit.

It will be noted that the conditions are substantially similar to those of a simple C.B. signalling circuit, i.e. the calling condition is transmitted on one line, and the supervisory signal is returned on the other line. The main difference is that, whereas in the d.c. case the signals continue during speech

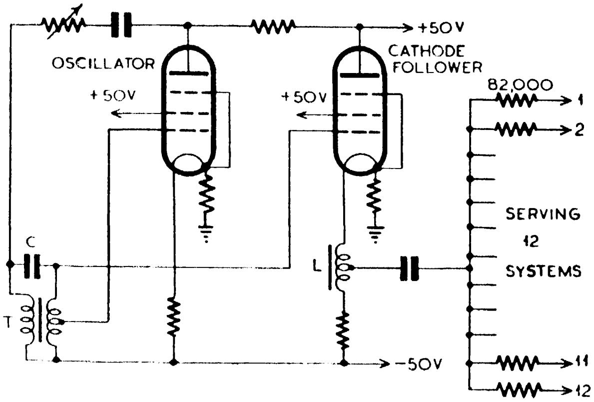


FIG. 699. CIRCUIT OF OSCILLATOR

and cease when the circuit is cleared, the 2 V.F. scheme provides for the cessation of the tones when speech commences and the re-establishment of the tones as a clearing signal until the connexion is broken down. The absence of tones during speech materially assists to reduce overloading of the transmission line amplifiers. Usually the same frequency is used for signalling on the "go" and "return" signalling sub-channels, but there is of course no reason why different frequencies should not be used if so desired.

The Oscillator. The oscillator (Fig. 699) is of the conventional type. There are 21 oscillators to

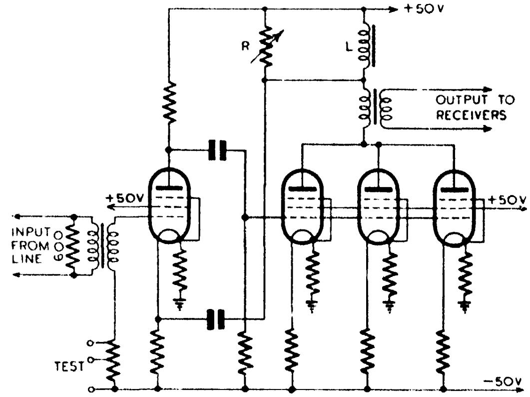


FIG. 700. CIRCUIT OF COMMON AMPLIFIER

provide the 21 signalling frequencies (350–2350 c/s), but each oscillator can serve up to a maximum of 12 separate systems. The first stage of the oscillator contains a pentode valve with the anode coupled to the control grid via a phase reversing resonant network. This is followed by a cathode follower stage, which acts as a buffer between the oscillator and line and effects the required impedance matching. The cathode follower choke L is arranged as an auto-transformer with the load taken off at the centre-point.

A normal speech channel covering the frequency range of from 300–2400 c/s has an attenuation frequency characteristic which can vary over a range of some 9 db depending upon the frequencies transmitted. In order to obtain a good impulsing performance, it is desirable that the signalling tone presented to the V.F. receivers should be of substantially constant level. The system therefore includes means of equalizing the levels of the transmitted tones at the sending end by the provision of a simple network just before the frequency is transmitted to line.

The Common Amplifier. The signalling tones of all sub-channels are transmitted along the "go" channel, and at the distant termination are applied to a common amplifier. Economies can be obtained by making the amplifier common to all the signalling circuits of one channel rather than on the basis of one amplifier for each V.F. receiver. It is extremely unlikely that in a system of 20 circuits all circuits will be signalling at the same time. The design is therefore based on the assumption that 8 sub-channels may be signalling simultaneously.

The amplifier circuit is shown in Fig. 700. It is a 2-stage circuit of conventional design with 3 valves in parallel for the second stage. A high degree of linearity is ensured by the provision of some 26 db of feed-back. The inductor L is required to shunt the feed-back resistor R in order

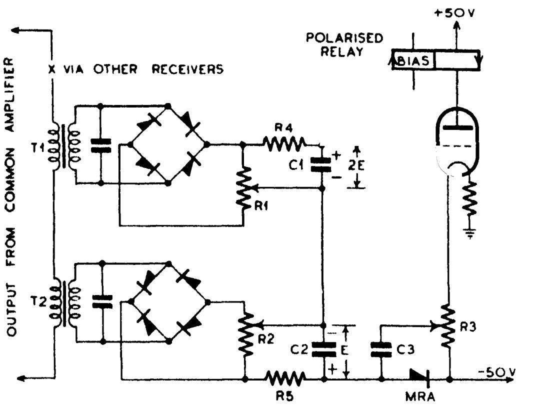


Fig. 701. Main Features of V.F. Receiver (Separate Signalling System)

to minimize the d.c. voltage drop in the anode circuit of the output stage.

V.F. Receiver. Fig. 701 shows the basic elements of the receiver used for the detection of the voice-frequency signalling currents and their conversion to direct current signals at the incoming exchange. The output from the common amplifier is connected to all the 21 receivers in series. The input of each receiver passes through the two tuned transformers $T1$ and $T2$. (The series arrangement is adopted to match the high output impedance of the pentode valves in the common amplifier.) Each transformer is tuned to the same resonant frequency, but the "Q" value (i.e. the ratio reactance/resistance) of transformer $T2$ is made half that of transformer $T1$. The output from the two transformers gives response curves as shown in Fig. 702. The higher "Q" value of $T1$ produces the larger and more sharply peaked wave, whilst the more damped circuit of $T2$ produces a less pronounced resonance at the tuned frequency. The outputs from the transformers are fed to bridge rectifiers, and the resultant current is passed through smoothing circuits ($R4$, $C1$, and $R5$, $C2$) to the potentiometers $R1$ and $R2$ which form the load on the incoming signal. The potentials developed across $R1$ and $R2$ are applied in series but with opposite polarity to the grid circuit of the valve. The effective potential thus applied to the grid is shown by the dotted curve in Fig. 702. By means of this arrangement, the selectivity of the receiver is increased without incurring the cost of a complex filter system. The waveform applied to the valve is equivalent to that which would be produced by a tuned circuit of many times the "Q" value of either of the constituent tuned circuits. This method of obtaining a highly selective receiver circuit is also of some advantage at low frequencies where it is difficult to obtain high "Q" values in the tuned circuits. The arrangements adopted do, of course, reduce the available voltage applied to the grid of the detecting valve. If the "Q" values of the two tuned circuits are made more equal, then a higher degree of attenuation outside the resonant frequency would be obtained, but the resultant output to the grid of the valve would also be reduced.

Although the transmitting level of the signalling tones is kept fairly constant by means of the pre-equalization networks, there will be variations in the received levels of the signals at the distant end due to random variations in the T.E. of the trunk circuit. In order to avoid impulse distortion as a result of such variations, the relay in the anode circuit of the valve is arranged so that it will operate and release at the half amplitude level of the received signal. Distortionless impulse repetition over a 6 db range of input levels is achieved by the bias level control which has been illustrated in Fig. 678.

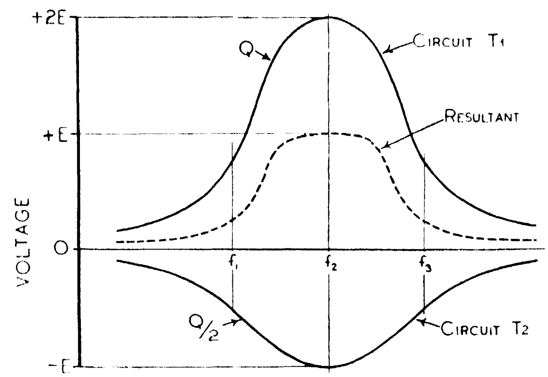


Fig. 702. Showing how High Selectivity is Obtained Without the Use of a Complex Filter System

Signal Channel Extracted from Speech Spectrum. We have seen that signalling on the normal speech channel suffers from the disadvantages that a more or less complex circuit must be provided to prevent imitation of the signalling currents by speech, and also that the necessity of avoiding signalling tones during the conversational period requires a complex pulse signalling technique. The

separate signalling system, on the other hand, involves the provision of a separate and costly channel for signalling purposes, and the segregation of speech and signalling into two separate channels has a number of disadvantages.

There is a further method of obtaining voice-frequency signalling on a long-distance trunk circuit. A comparatively narrow frequency band —say 100 to 200 c/s—is required for the signalling path. It is possible to provide electrical filters in the normal speech channel so that a narrow band of speech frequencies is excluded from the transmission line (Fig. 703). This narrow band can then be used as a separate signalling channel.

The extraction of a band of frequencies from the normal speech spectrum will, of course, degrade the quality of transmission. Some investigations have been made to determine the extent to which the speech is likely to be degraded by the extraction of a narrow band of frequencies. Fig. 704 shows the effect on the transmission efficiency of deleting 200 c/s bands from various parts of the speech-frequency range. The loss of transmission efficiency is expressed as the equivalent amount of attenuation (in decibels) which would produce the same degradation of articulation as the exclusion of the 200 c/s band. As is to be expected, the greatest effect on the articulation efficiency is produced when a signalling band of the order of 1000 c/s is selected. As the mean frequency of the band is increased or decreased from this value, the articulation loss falls progressively. It is clear that, in

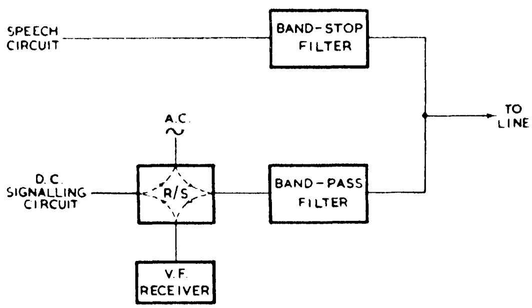


Fig. 703. Block Schematic of Suppressed Frequency Signalling System

order to avoid undue interference with speech transmission, the signalling band should be selected outside the range of, say, 400 to 1600 c/s. The lower or the higher the frequency, the less is the interference with the articulation efficiency of the circuit.

The effective transmission band of different trunk lines varies very considerably. Some of the earlier heavily loaded circuits may have a cut-off frequency as low as 2500 c/s. Similarly the terminal equipment may produce a rapid rise of attenuation on frequencies below, say, 400 c/s. There is therefore some difficulty in selecting a

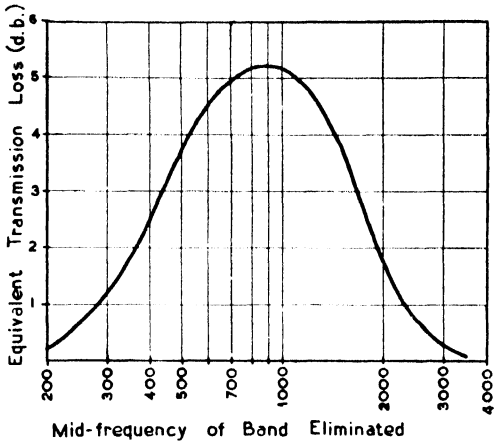


Fig. 704. Transmission Loss Introduced by Extraction of a 200 C/S Band

signal-frequency band which on the one hand will cause a minimum degradation in the articulation efficiency of the circuit, and which will at the same time give satisfactory transmission of the signal frequencies over lines and exchange equipment of various types.

Difficulties are also likely to arise if signalling tones are transmitted during the conversational period. Any such signals tend to overload the line amplifiers and, unless there is perfect linearity in the transmission system, interference with speech is likely to occur due to the generation of harmonics of the signal frequencies. It may also be necessary to provide guard circuits against speech imitation in order to prevent the possibility of false signals due to harmonics of the speech frequencies which may fall within the signalling band.

International 2 V.F. Signalling Code. To facilitate international communication, it is desirable that there should be a universal system of signalling on long-distance telephone circuits. With this object in view, the International Telephone Consultative Committee (C.C.I.F.) have recommended (C.C.I.F. Conferences: Montreaux 1946, Paris 1947, and London 1948) an international 2 V.F. signalling code. There are two basic signalling tones, X and Y, with frequencies of 2040 c/s and 2400 c/s respectively. These tones can be applied individually to line or in the form of compound signals consisting of both frequencies transmitted together.

Six different types of signal are recommended, viz.:

X = Short pulse (60–100 msec) of 2040 c/s tone.

Y = Short pulse (60–100 msec) of 2400 c/s tone.

XX = Long pulse (240–360 msec) of 2040 c/s tone.

YY = Long pulse (240–360 msec) of 2400 c/s tone.

C = Short pulse (40–60 msec) of compound tone.

CC = Long pulse (120–200 msec) of compound tone.

The proposals envisage the use of these signals as follows:

Seizure signal—CX or CY.
Proceed to send—X or Y.
Impulsing—X and Y coded pulses (see Fig. 687).
End of impulsing—Spare binary code $XXXX$.
End of selection signal—C.
Called number busy—CX.
Called subscriber being rung—CY.
Called subscriber answer—CCY.
Backward clear—CCX.
Clear forward—$CCYY$.
Backward release guard—$CCYY$.
Forward transfer—$CCXX$.
Extended busying signal—CCX.

A number of spare binary codes ($XYXX$, $XXYY$, etc.) is available for miscellaneous purposes. These signals can be used, if desired, for reverting a call to an inward operator, for the control of echo suppressors, and so on.

EXERCISES XXII

1. Explain the principles of operation of any three systems of transmitting a "number" over a junction or trunk line by means of impulses or code signals. Give an indication of the length and type of line over which each of the three systems described could be used. What other factors would determine the choice of such systems in an exchange network? (*C. & G. Telephony, Grade III*, 1946.)

2. Describe how the shape of a direct current impulse is modified in the course of its transmission over a long trunk line. How do the electrical characteristics of the terminal equipment modify the shape of the received signal?

3. What are the advantages of a "double-current" impulsing scheme? Give two examples to show how double-current effects can be obtained by the use of a single battery.

4. Describe the principles underlying a method of direct current dialling suitable for use over long lines. State the factors that limit the distance over which this method of working may be employed. (*C. & G. Telephone Exchange Systems III*, 1949.)

5. Describe the construction and the principle of operation of one type of polarized relay which is particularly suitable for use on a long-distance d.c. dialling circuit.

6. Show by means of sketches of the essential circuit elements how the direct current impulses, dialled by an operator in a voice-frequency signalling and dialling system, are converted and transmitted to line as alternating current pulses, and reconverted to direct current signals suitable for operating the selectors at the distant end. Show on a chart the duration of the make-and-break periods of the relay contacts concerned with impulsing.

When number-unobtainable tone is returned from the distant end, it is not transmitted continuously over the trunk line. Explain the reason for this. (*C. & G. Telephone Exchange Systems III*, 1948.)

7. Describe, with the help of suitable diagrams, how the signal applied to the relay operating stage of a V.F. receiver can be kept at substantially constant level when the amplitude of the incoming line signal varies. Which of these devices also cater for variations in the characteristics of the amplifying valve?

8. Give two circuit elements suitable for use in the detection stage of a V.F. receiver. What arrangements are made in these circuits to minimize the degree of impulse distortion?

9. Explain with the aid of a diagram of the circuit elements concerned, how voice operation is guarded against in a voice-frequency signalling and dialling system. (*C. & G. Telephone Exchange Systems III*, 1949.)

10. Discuss the relative merits of voice-frequency signalling systems in which:

(*a*) the signals are transmitted over the speech path,

(*b*) the signals are transmitted over separate channels reserved for that purpose,

(*c*) a narrow band of frequencies is extracted from the speech path for signalling purposes.

CHAPTER XXIII

TRUNK AND TOLL MECHANIZATION

In earlier chapters it has been seen that the adoption of automatic switching methods enables appreciable economies to be made in the cost of handling traffic in a local network. A very large factor in these economic considerations is the saving in the number of telephonists required for the establishment of calls. A somewhat similar argument can be advanced for the automatization of the trunk network. So long as manual trunk switching methods are retained, the establishment of a trunk call may require the services of a telephonist at the originating group centre, at two or more zone centre exchanges, and at the terminating group centre. Any reduction in the number of telephonists will result in an economic improvement, provided that the annual charges of the equipment installed to give automatic switching are less than the wages, the establishment costs, etc., of the telephonists.

Although the considerations are broadly the same as those for the automatization of a local network, there are nevertheless several important differences which should be borne in mind. Long-distance trunk calls involve the use of long and expensive external cables with costly amplifying equipment at frequent intervals along the line. The total annual charges for the "transmission path" provide a very substantial proportion of the total cost of the trunk service. The cost of switching such calls is comparatively small in relation to the transmission plant costs, and hence any savings obtained by improved switching methods have only a limited effect on the total cost of providing service. On the other hand, automatic switching has a number of service advantages, particularly in the speed at which calls can be established. This latter factor also results in a lower ineffective time on the expensive trunk circuits, so that a higher value of "paid time" can be obtained per circuit.

As we have seen in earlier chapters, direct dialling by the subscriber is permitted on all calls up to 15 miles radius from the originating exchange. It is the present policy of the Post Office that calls over greater distances shall be set up by a telephonist who will be provided with extensive facilities for dialling the required number over an automatic trunk switching network.

Ultimately it may be possible to permit subscriber-dialling over greater distances than at present, and by so doing to reduce the number of telephonists required for the establishment of toll and trunk calls. It is quite conceivable that, at some date in the future, subscribers will have facilities for dialling any subscriber in the British Isles. The elimination of telephonist control on long-distance calls introduces a number of service questions which must be carefully considered before a policy of subscriber-to-subscriber dialling can be introduced. The main questions which arise are:

(*a*) Is it good policy to place the full responsibility of establishing a long-distance and expensive call on the subscriber? Such calls must of necessity require the use of more or less complex dialling codes, and the process of setting up a difficult long-distance call may be beyond the capacity of some telephone users.

(*b*) The present system of recording the charges for local calls by means of a unit counting meter is not satisfactory for recording the charges on long-distance calls. Whilst it may be reasonable to ask a subscriber to accept an account in which all calls up to 4 units are bulked—with no means of analysis—it is doubtful if the subscribers would accept a system which did not provide a means of detailing the separate charges for long-distance calls. If this principle is admitted, then the adoption of subscriber-dialling for trunk calls must be accompanied by some means of recording full details of the call, i.e. date, time, number of called party, etc. Not only is a machine required which will produce all these details, but this machine must also be capable of associating the automatically produced call ticket with the correct calling subscriber's number. This involves the provision of calling subscriber identification equipment at each exchange.

(*c*) Long-distance trunk circuits are expensive to provide and the importance of reducing ineffective time on such circuits has been stressed. The subscriber must be considered as an unskilled operator, and if he is allowed access to the main trunk network there will be a tendency for the ineffective time to rise (e.g. the caller may hold on to busy tone conditions, etc., for prolonged periods).

(*d*) The present trunk operating procedure makes provision for a limited amount of secondary routing of calls should the primary route be congested.

This facility could not be provided under subscriber-dialling conditions without the use of more or less complex automatic re-routing equipment.

(*e*) Anything up to 10 impulse trains might be required to establish a call over a difficult routing. The number of digits to be dialled by the subscriber could only be reduced by the adoption of complex and expensive translation equipment. Unless translation is available, the instructions to the subscriber would tend to become very complicated and the directory problems would be accentuated by routing changes.

(*f*) The presence of a telephonist at the originating end of a long-distance call produces a very valuable smoothing effect on the traffic. The originating traffic from the subscribers is pure chance distribution, and if this traffic is applied direct to the trunk line system a more lavish provision of trunk circuits is necessary to give the same quality of service to the subscriber.

(*g*) The introduction of subscriber-to-subscriber dialling might possibly produce a material increase in the volume of enquiry traffic.

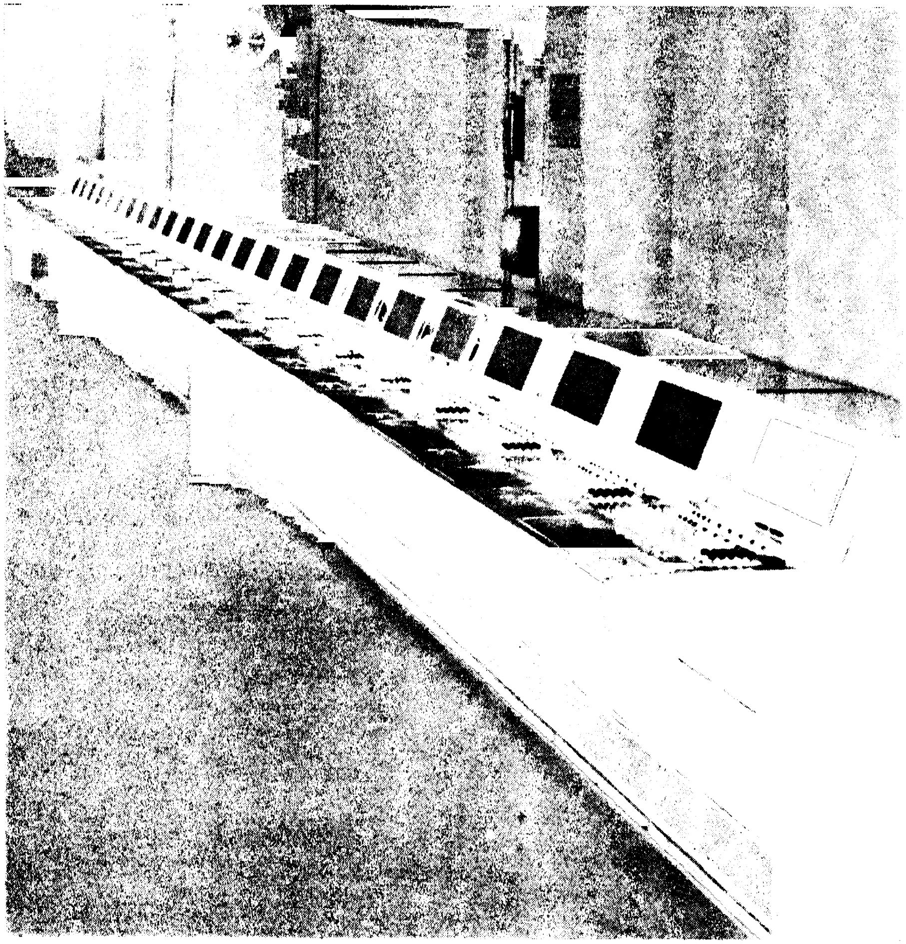


FIG. 705. A TYPICAL SUITE OF CORDLESS SWITCHBOARDS (INTERSTATE POSITIONS)

Until such time as conditions permit the extension of subscriber-dialling, a high degree of efficiency can be obtained by providing an automatic trunk network for the use of the originating trunk exchange operator and by installing automatic aids wherever possible to minimize the amount of telephonist attention required per call.

At the time of writing, the British automatic trunk switching scheme is in the process of development and hence it is not possible to give more than the broad outline upon which the system

will be based. Several other telephone administrations have developed automatic trunk switching schemes in the past few years and a description is given of one such system which is, in many respects, similar to the proposed British standard scheme.

THE MELBOURNE AUTOMATIC TRUNK SYSTEM

During the years 1940–1944 the Australian Post Office installed an extensive system of automatic trunk switching throughout the State of Victoria. The main trunk switching centre of the network is located at Melbourne, where more than half of the total trunk traffic is now switched on a fully automatic basis, the remaining traffic being handled on a semi-automatic basis. All calls from the Melbourne area which require the preparation of trunk tickets are routed through demand operators, and all incoming calls from neighbouring states are also handled at the Melbourne trunk positions. Most of the traffic from the provincial centres to subscribers in the Melbourne automatic area is dealt with on an automatic switching basis.

The majority of the trunk routes within the State of Victoria are provided by overhead lines. Some of these circuits utilize physical conductors, some are routed over phantom circuits, whilst other routes are based on carrier systems. The main trunk routes to neighbouring states are, generally speaking, served by carrier current systems. (The trunk route to Hobart, Tasmania, is routed over a co-axial submarine cable across the Bass Straits.)

The equipment for the trunk switching scheme was designed and installed by Messrs. Siemens Bros. to the requirements of the Australian Post Office. The automatic trunk switching train is based upon the use of the motor uniselector which, by virtue of its high speed of search and its large bank capacity, is particularly suitable for trunk switching purposes. Advantage was taken of the changeover to automatic trunk working to redesign the trunk switchboards in order to facilitate the handling of traffic and to provide a number of new service facilities. These new trunk switchboards are of an attractive desk type with cordless connecting circuits.

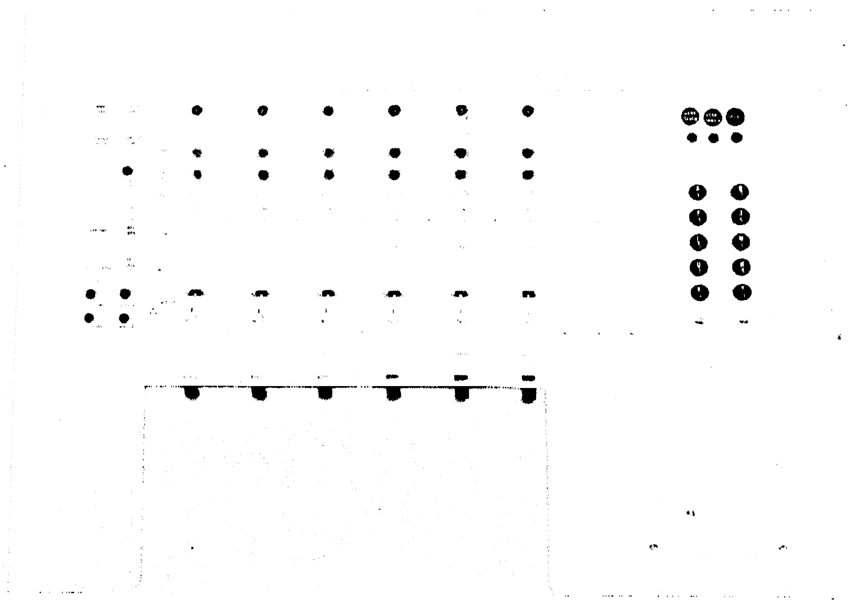


FIG. 706. ARRANGEMENT OF KEYSHELF—DEMAND AND SUSPENSE POSITIONS

Switchboard Design. All the positions are of the desk type with a horizontal keyshelf. The sloping face of the position carries a bulletin frame, the pneumatic tube outlet valves, and a strip of signal lamps. The keyshelf contains the various keys and lamps associated with the connecting circuits.

All the signalling and switching equipment (apart from the control keys and supervisory lamps) is located away from the positions in the apparatus room. The design is such that the operator can readily see over the top of the position. This low height offers a very considerable improvement over the taller manual trunk positions in respect of illumination, supervision, ventilation, and the lay-out of the switchroom. The normal trunk position width of 27 in. has been retained. Altogether

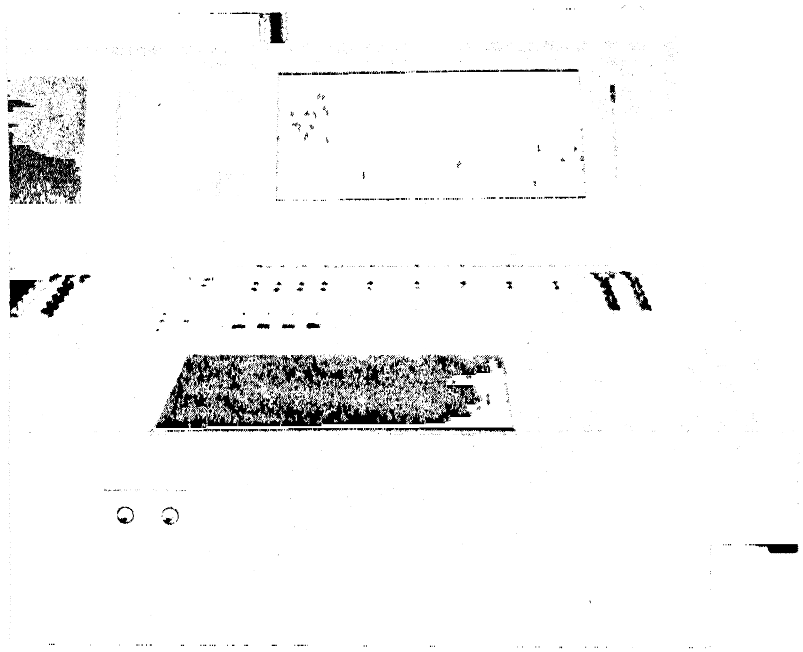


FIG. 707. CLOSE-UP VIEW OF INTERSTATE POSITION
(Note thermometer type lamp display on right of panel)

the installation at Melbourne consists of four main suites with a total of nearly 100 operators' positions. All the positions (with the exception of the delay supervisor's desk) are of the same general design (Fig. 705).

The first suite consists of some 59 demand positions for the handling of the originated trunk traffic from subscribers in the Melbourne automatic area. The keyshelf lay-out of the demand position is illustrated in Fig. 706. Each position is provided with 6 connecting circuits, each circuit being equipped with:

A chargeable time clock.

A combined speak/monitor key.

A time check lamp.

Answering and calling side supervisory signals

An engaged lamp.

A release key.

To the left of the keyshelf is a number of common keys (e.g. speak answer/speak call, release answer release call, call monitor/sender changeover, etc.) To the right of the keyshelf is the digit keystrip which is arranged as two rows each of five keys plus two common keys (send answer/send call). These digit keys are used for the setting up of all calls. The sloping panel of the position is largely occupied by a glass-fronted bulletin frame which contains information such as routing code numbers, etc. An interesting feature is the provision of a number of lamps (e.g. call monitor, etc.) behind the bulletin glass. When lighted these lamps show up as discs on the bulletin panel. A vertical lamp strip to the right of the bulletin frame gives information to the telephonist of the number of calls which are awaiting attention and of excessive delay in answering.

A suite of 7 through positions caters for the traffic from provincial exchanges which, for

various reasons, must be routed through the manual switchroom at Melbourne. These positions are of the same general design as the demand positions, except that 10 connecting circuits are provided per position.

A third suite of 24 interstate positions is provided for dealing with traffic which involves connexion with exchanges in other states. Such traffic is always dealt with on a delay basis and hence, although the positions are of the same general design as the demand and through positions, the keyshelf equipment is somewhat different (Fig. 707).

There is also a small suite of suspense positions equipped similarly to the demand positions and intended for dealing with traffic which cannot, for some special reason, be handled by the normal operating positions. This is supplemented by a trunk enquiry suite of six positions which deals mainly with enquiries from Melbourne subscribers.

A feature of the exchange is the provision of a delay supervisor's desk equipped with a wide range of facilities by means of which it is possible to supervise the general flow of traffic through the exchange. The desk is of special design (Fig. 708) and contains various keys and "thermometer type" lamp displays. Facilities are provided at this position for observing the number of calls awaiting circuits on the various outgoing trunk routes and the number of calls which are awaiting the attention of the operators. Lamp indications are also given of the number of staff on the various suites and of the answering delay. A series of keys is provided for switching to delay working on any particular route and for providing an indication to the operators of the approximate time of delay. It is also possible to withdraw alternative routing facilities if the traffic conditions make such a course desirable.

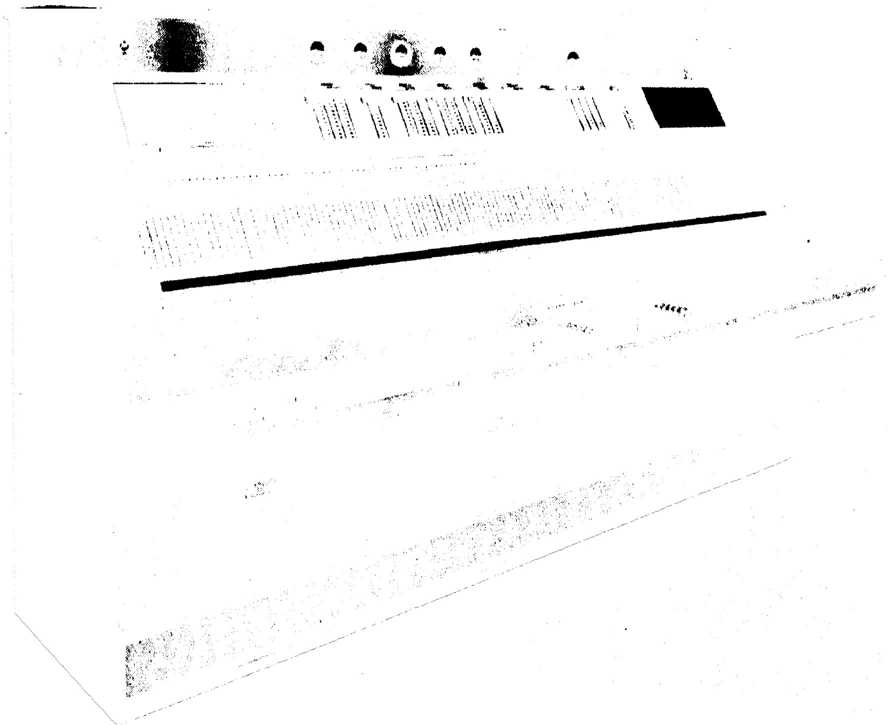


Fig. 708. Delay Supervisor's Desk

Traffic Incoming to Trunk Switchboard. The demand circuits from the local automatic network terminate on standard 25-point uniselectors, the banks of which are graded to a number of demand distributors (Fig. 709). The demand distributors are of the Siemens high speed motor type with a capacity for 200 outlets to position connecting circuits. This capacity is sufficient to give full availability to a group or *field* of 28 positions. The

trunking arrangements are such that the incoming demand traffic is divided into a number of separate distributions, each distribution being served by one group of demand distributors and 28 demand positions. Each demand position has 6 connecting circuits, so that a total of 168 of the distributor trunks are routed to the connecting circuits of regular demand positions.

In the Melbourne scheme, there are 2 distribution groups for demand traffic (each of 28 positions) together with a separate group of 3 *link* positions. These link positions have 6 connecting circuits which appear on the banks of both groups of demand distributors. The link positions are provided to equalize the day loads on the 2 distributions, and also to concentrate the traffic during the night or at other times of light load. The link positions are automatically switched to balance the load on the two main distribution systems. For example:

(*a*) When there are no calls on either distribution, the connecting circuits of the link positions are switched to operate on both distributions.

(*b*) When calls are waiting to be answered, the link positions are switched to the distribution which has the larger number of waiting calls.

(*c*) When the speed of answer on one distribution system is greater than the predetermined time, the link positions are switched to that distribution, regardless of condition (*b*) above.

(*d*) When the speed of answer is longer than the predetermined period on both distributions, the link positions are switched to the distribution which has the larger amount of waiting traffic.

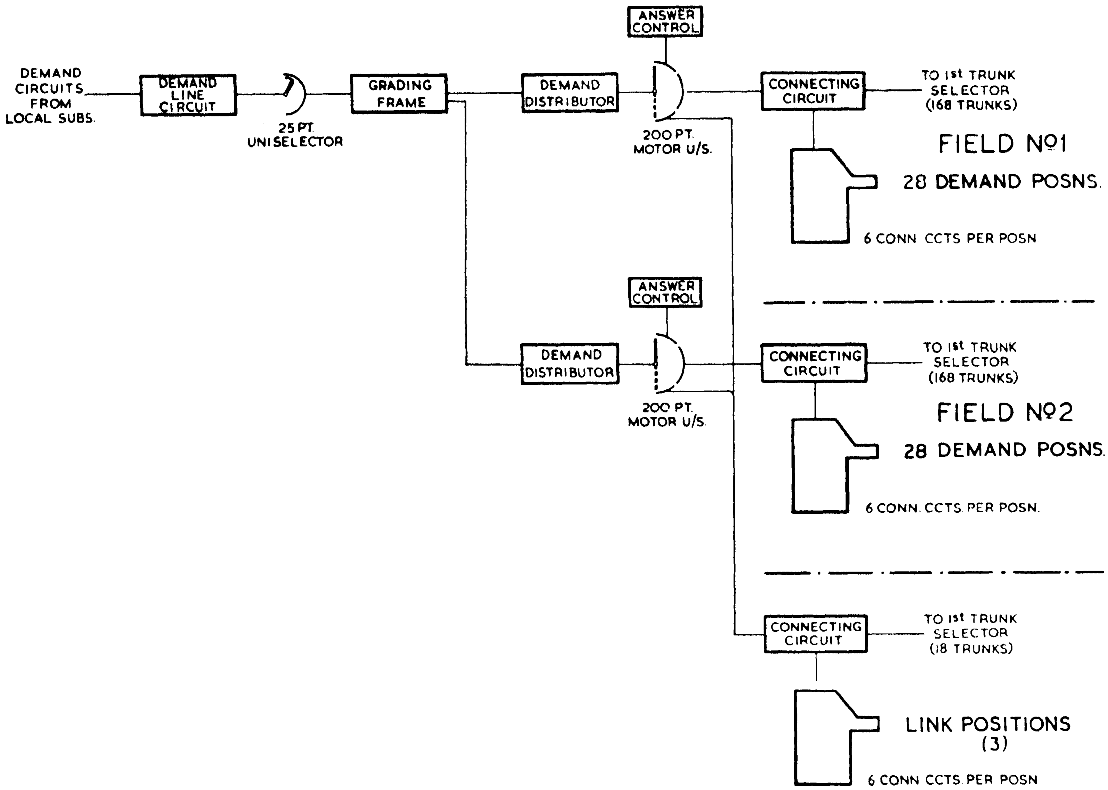


Fig. 709. Distribution of Traffic to Demand Positions

(*e*) During periods when the traffic in both distributions is substantially equal, and when the time of answer on both distributions is either shorter or longer than the critical time, the link positions are switched to one distribution for so long as this condition is maintained.

The 3 link positions (with the 6 connecting circuits per position) absorb a further 18 trunks on each of the distributor groups, thereby providing a maximum total of 186 outlets per distribution.

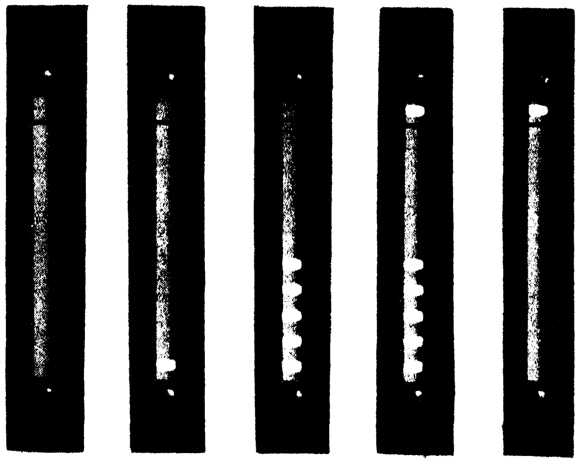
Queueing of Incoming Demand Calls. Ten positions on the contact bank of each demand distributor are reserved for the queueing of incoming calls. If all the telephonists in the

distribution group are busy with calls, or if all the connecting circuits in the group are engaged, the arrival of a further call causes the selected distributor to hunt until it finds an outlet in its contact bank which has been allocated as the first free position in the queue. There are 10 such queue positions, so that a maximum of 10 calls per distribution can await the attention of an operator. The queue positions of the distributor bank are connected to an *answer control* circuit, which determines the order in which the queued calls shall be released for attention. Throughout the waiting period, each queued call remains on the same contact of the demand distributor, but the answer control circuit maintains the order of precedence and, as each call is answered, the control circuit determines the next call in the queue. When a particular call comes to the head of the queue, the receipt of a call acceptance signal from any of the operators causes the demand distributor to move from the queue section of the contact bank and to search for the connecting circuit (as marked by the operation of the speak key).

If no calls are queued in the answer control circuit when a fresh call arrives, and an operator has set up a call acceptance condition, the call is routed direct to the appropriate connecting circuit without having to enter a queue. A timing device is associated with each queue to register the period of waiting. If a predetermined maximum waiting time is exceeded, an urgent alarm signal is displayed on all the associated positions and on the delay supervisor's desk.

Each demand position is provided with a calling load display. This display is in the form of a vertical strip of lamps which is mounted at the right hand of the sloping face of the position. Fig. 710 shows typical conditions. At *A* no lamps in the display are glowing, thereby indicating that no calls are awaiting attention. *B* indicates that one call is awaiting answer, whilst *C* shows the appearance of the display when five calls are awaiting the attention of a telephonist. *D* indicates that there are five calls awaiting answer, but the flickering of the top lamp shows that the waiting time is excessive. If the position is ready to accept incoming calls immediately, the top lamp glows steadily as shown at *E*.

The Setting up of Outgoing Calls. A first trunk selector is associated with each demand position connecting circuit, and the calling signal from the subscriber is extended through this selector to light the appropriate supervisory lamp (Fig. 711). The operator answers by throwing the speak key, and ascertains the number required. All calls, irrespective of their destination, are extended from the trunk positions by the operation of digit keys. The appropriate digits necessary to route the call to the required subscriber or to special positions (such as the Delay Supervisor's Desk) are transmitted by the consecutive operation of the required digit keys. The use of high speed relays enables the digit keys to be operated as fast as the telephonist wishes, the only stipulation being that she must operate and release the keys fully at all times. There is no limit to the number



A *B* *C* *D* *E*

FIG. 710. WAITING CALLS DISPLAY STRIP

A = No calls waiting attention
B = One call awaiting answer
C = Five calls awaiting answer
D = Five calls awaiting answer, waiting time excessive
E = Position ready to accept incoming calls

of digits which can be employed to route the call to the required destination.

The depression of a send key on the digit keystrip causes the coupling motor uniselector associated with an idle sender to search for the operator's position. As soon as the position is switched through to the sender, a "sender taken" lamp lights to indicate to the operator that she can proceed to set up the required number on the digit keys. The signals from the digit keys are in the form of direct current signals over combinations of four wires to the sender.

The Keysender. After receiving the signals from the digit keystrip, the sender first transmits the code signals to control the movement of the motor uniselectors (i.e. the first and second trunk selectors) within the trunk exchange. The trunk selectors are controlled by instantaneous code signals over four wires from the sender. As each

trunk selector finds an outgoing trunk in the required group, it sends back a signal to the sender which determines the subsequent operations of the latter. After the positioning of the trunk selectors, the controlling signals from the sender depend upon the type of signalling required on the selected route. For example, if the call is to a provincial exchange where 2 V.F. signalling is employed over the trunk route, the appropriate 2 V.F. signals are transmitted direct from the sender. Similarly, if the call is to a nearby automatic exchange, Strowger impulses are sent out to step the selectors at the distant termination. In other cases (e.g. where the primary route terminates at a manual exchange) the sender cuts out immediately since no further routing signals are required.

The senders are fitted with a self-contained impulse generation circuit of the type considered in Fig. 244. The elimination of common impulsing machines (serving a number of senders) has some advantages in the prevention of major breakdowns. Apart from this, however, this particular type of circuit enables the impulse frequency to be modified to suit the characteristics of the route over which the signals are being transmitted. On routes to nearby exchanges a high impulse frequency can be employed, whilst on the more exacting routes the speed can be reduced to an appropriate value.

The routing digits keyed up by the telephonist are completely independent of the routing of the call. This facility requires the use of a translator associated with the sender, but gives a high degree of flexibility in the trunking arrangements, and also materially simplifies operating procedure.

There is one translation field which is common to each group of five senders. The cross-connexions on this translation field enable the appropriate engineering routing to be set up for any desired system of code digits from the keystrip. The use of a common translation field per five senders minimizes the amount of work required when a re-routing is necessary. Moreover, by limiting the translation field to a maximum of five senders, it is possible to make routing changes during periods of light traffic with very little interference to the operation of the system.

A fault on any sender can affect five trunk positions. In order to prevent such a fault from putting these positions out of service, facilities are provided so that any operator can obtain access to an alternative sender, should the normal one become faulty.

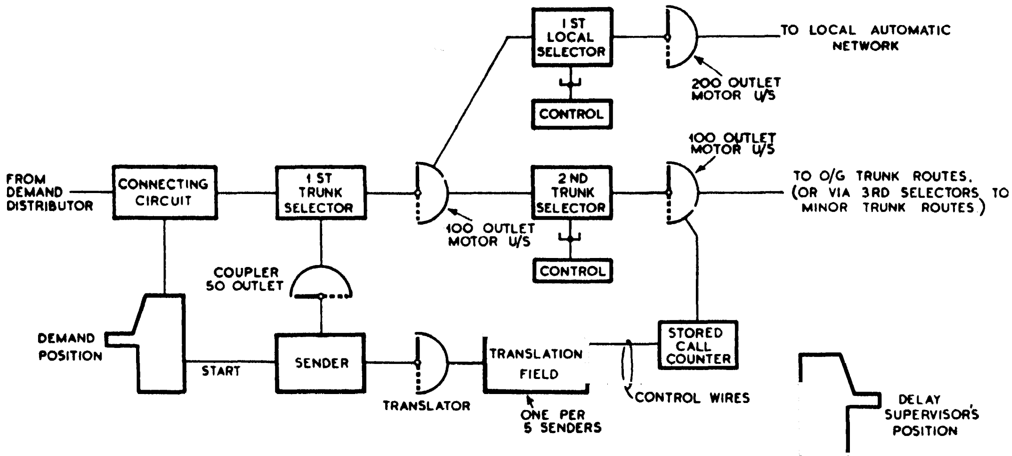


FIG. 711. GENERAL ARRANGEMENTS OF TRUNK SWITCHING TRAIN

Alternative Routing. The senders are arranged to provide an extensive range of alternative routing facilities. On receipt of the digit key code for a particular trunk group, the sender applies a test to determine if the required group is congested and, if so, whether the call is to be routed over an alternative trunk group. If the primary group of trunks is congested, then an attempt is made to complete the call over a specified alternative route. If, however, the secondary route is also congested, the call is directed to await an outlet on the main primary route. Generally speaking, every call passed via the secondary route involves one intermediate switching point. If this intermediate exchange is manual, then the trunk operator is given a lamp signal from the sender to warn her that she will receive an answer, not from the terminal exchange but

from an intermediate operator. In other cases the intermediate exchange is automatic, and in these circumstances the sender automatically transmits the digits necessary to route the call forward to the terminal exchange. If congestion is encountered on the automatic equipment at the intermediate exchange, a voice-frequency signal is returned to the originating sender. This signal causes the sender to release the connexion via the secondary route and to direct the call to await a free outlet in the primary group.

The translation field of the sender is connected to the Delay Supervisor's desk in the trunk switchroom in such a way that, when the supervisor places any particular route on delay working, the information is passed forward by the sender to the operator. These signals indicate not only that the route is in delay, but also the estimated period of delay in each case.

Call Storage. During periods of momentary heavy traffic, the operator may encounter congestion conditions on the required route. The sender controls the trunk selectors in the usual way, and if all outlets in the required group are engaged the call is routed to storage equipment associated with the last trunk selector. When this happens, a special signal is returned to the operator to advise her that the call is in storage. A separate and distinctive signal is returned to the operator in cases where a large number of calls are held in storage, so that the telephonist can decide whether it is worth while asking the caller to wait at the telephone, or whether she should inform him that he will be recalled when the connexion is established.

The automatic equipment provides for a continuous search of the required outgoing trunk group whenever there are calls in storage for that group. The operators who have calls in storage are reminded of the fact by means of a fleeting signal every 6 sec on the connecting circuit supervisory lamp. During the period of waiting, the telephonist can proceed with other work. When a trunk in a certain group becomes free, a lamp signal is returned to all the connecting circuits which have a call in storage for that particular group. Any operator can then seize the circuit by throwing the appropriate speak key.

The call storage circuits do not provide for the queueing of calls. The arrangements are such that the free trunk is allocated to the first operator who accepts the circuit. The unsuccessful operators are again given the storage signals to await the next free line. This principle is used in preference to the queueing scheme, since the first operator who sets up a call in the storage equipment may, when a line becomes free, not be able to attend to that call because she is engaged on other calls. If queueing were adopted it might mean that certain trunk lines would be reserved for some time awaiting the attention of an operator, and this would in turn materially reduce the paid time on the trunk circuits.

The call storage equipment is designed on the assumption that no call will remain in storage for more than 10 minutes or, alternatively, that not more than 5 per cent of the total traffic will be subject to storage. If these limits are exceeded,

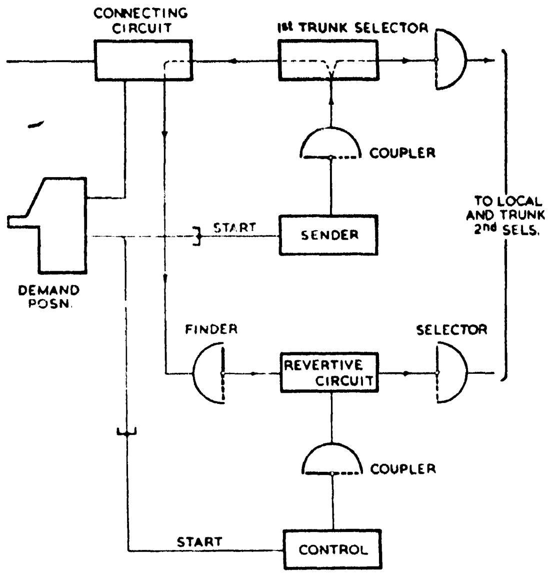


FIG. 712. METHOD OF SETTING UP "REVERTED" CALL FROM DEMAND POSITION

then delay working should be introduced on the route in question.

Revertive Traffic. Where it is not possible to complete a call "on demand," the caller is normally asked to replace his telephone and to await a recall. These conditions make it necessary for the demand position operator to set up an outgoing call from the answering side of a connecting circuit (i.e. the side of the connecting circuit which is connected to the call timing device). This revertive traffic is catered for by the provision of revertive control apparatus which is common to the exchange, and is accessible from all the connecting circuits (Fig. 712). The operator signals that she wishes to set up a revertive connexion by the operation of a press button on her position. This forwards a signal over a start wire to the revertive control relay group, and causes the associated coupler switch to find a disengaged

revertive selector circuit. Associated with this selector circuit is a finder switch, which automatically hunts for the connecting circuit on which the call is to be established. At the same time the operation of the press button causes a sender to search for and be coupled to the operator's position. When this circuit is ready for the operator to key up the number, a lamp signal is given to the telephonist who keys up the call in the usual way. The appropriate outgoing control signals from the sender are passed via the first trunk selector and the revertive selector, and thence via the banks of the latter to first local selectors or to second trunk selectors as required.

An interesting feature is a system of transmission bridge switching in the first local selector

When a circuit has been switched to delay working, any demand operator who keys up the code of the trunk group is given a delay lamp signal. There are three types of delay signal, i.e. a flickering signal which indicates that the probable delay is of the order of 15 minutes, a flashing signal indicating that the probable delay is about 30 minutes, or a steady glow which indicates that the probable delay is 45 minutes or more. The introduction of delay working automatically prevents the use of this trunk group as an alternative route. This facility prevents the complications which often occur in a trunk network where alternative routing is employed.

Incoming and Through Traffic. Fig. 713 shows the main switching scheme for calls incoming to

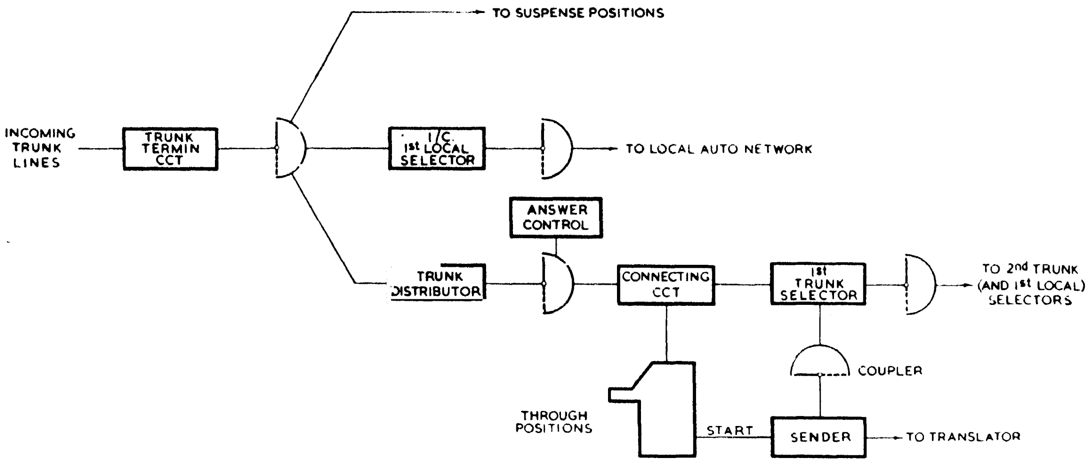


FIG. 713. SWITCHING SCHEME FOR INCOMING AND THROUGH TRAFFIC

circuits. These selectors are equipped with transmission bridges which are brought into circuit only after the call has been established by the sender. By this means the transmission bridge can be inserted at will, depending upon the set-up of a particular call.

Delay Working. The arrangements of the Melbourne scheme allow of any demand position to be used for delay working. The allocation of the positions is controlled by the Delay Supervisor who, by operating a key on her desk, gives the demand position operator access to the trunk group whilst the group is barred to all other operators. The necessity for delay working is determined by the number of calls which is stored in the particular trunk group. Delay working can be introduced automatically when the number of calls stored reaches a predetermined number. Alternatively, the Delay Supervisor can decide when to introduce delay working on any route.

the Melbourne area and for traffic which is switched through the Melbourne trunk exchange. The incoming trunk lines are terminated on suitable relay sets with a motor uniselector associated with each circuit. The trunk terminating relay sets provide facilities for directing any call either to the local switching train, to the through positions of the trunk exchange, or to a group of special "suspense" positions. Discrimination is effected by means of a prefixing digit dialled by the distant operators. If the call is to be routed via a through position, the dialling of the appropriate prefix digit causes the terminating uniselector to seize a trunk distributor, the banks of which give access to the connecting circuits of all the positions on the "through" suite. An answer control circuit is provided so that incoming calls can be queued up to await answer. After ascertaining the destination of the call, the through position operator keys up the routing code and the subscriber's

number into a sender in the usual manner, and the sender then transmits the necessary signals to position the 1st trunk selector and subsequent switches.

2- and 4-wire Switching. The trunk circuits terminating at Melbourne may be worked either on a 2-wire or on a 4-wire basis. The trunk switching scheme must therefore provide for:

(*a*) the switching of a 2-wire circuit to another 2-wire circuit;

(*b*) the switching of a 2-wire circuit to a 4-wire circuit;

(*c*) the switching of a 4-wire circuit to a similar 4-wire circuit.

In general, calls in the first two categories are switched on a 2-wire basis, whilst on calls of type (*c*) the switching is done on a 4-wire basis. The necessary discrimination is effected by the trunk line terminating relay sets which determine whether or not switching in any particular case is to be on a 2-wire or a 4-wire basis. One of the chief advantages of 4-wire switching (where this is possible) is that there is an overall gain of approximately 6 db due to the elimination of the losses in the 2- to 4-wire balancing networks.

The trunk terminating relay sets also include attenuation pads which can be switched in or out of circuit as required to obtain the desired overall transmission level. These attenuation pads are also used to suppress surges which may occur during dialling and switching. The main trunk terminal circuits are of a universal type so that, by suitable strapping arrangements, they can be used on any type of trunk line.

Voice-frequency Signalling. All the main trunk routes radiating from Melbourne are worked on a bothway basis with V.F. signalling. A 2-frequency signalling system is employed utilizing the standard X and Y tones as used on the current British V.F. system (i.e. $X = 750$ c/s, $Y = 600$ c/s). Each signal comprises one or more pulses of a definite length consisting of one of these frequencies. The two frequencies are not used simultaneously.

The V.F. receiver is of comparatively simple design. It consists of an initial amplifier which incorporates a voltage limiting device. The output from the amplifier is fed to two tuned circuits which respond to the X and Y signalling frequencies. The output from each of these tuned circuits is rectified and is applied to an anode-bend detector valve which includes a high speed relay in its anode circuit. Immunity from signal imitation by speech is obtained by a guard circuit which is broadly tuned to the first sub-harmonic of the signal frequencies. The output of this guard circuit is used to apply bias to the control grids of the detector valves in such a manner that the sensitivity of the receiver to signal frequencies is greatly reduced (see Chapter XXII). Further safeguards against false operation by speech are provided by delay features in the relay group associated with the V.F. relay set.

Special regard was paid in the design of the V.F. receiver to producing a unit which would be small in size and which would have a minimum power consumption. At the larger trunk exchanges the V.F. signalling currents are produced by inductor type generators of the type used in British practice. At the smaller provincial exchanges the tones are produced by valve oscillators. An interesting feature of the V.F. signalling system is the provision of tuned whistles so that operators or maintenance staff can signal over the trunk circuits in the event of failure of the signal tone supply.

Miscellaneous Facilities. The Melbourne automatic trunk switching scheme provides a number of other features which it is not possible to describe in detail here. Possibly the most interesting of these are:

(*a*) Routiners are provided for all the main switching circuits and for the voice-frequency signalling circuits. Motor uniselectors are employed for obtaining access to the apparatus under test. The routiner for the V.F. circuits includes a variety of transmission tests, and tests to check the length of the various V.F. signals. Facilities are also provided to check the release lags of most of the slow release relays in a V.F. signalling circuit.

(*b*) A trunk line detector is provided to check that all busy trunks are engaged on genuine calls and are not locked out of service in any irregular manner. (The necessity for this detector circuit arises from the use of pulse code signals on the V.F. signalling system.)

(*c*) The group pairing principle, already described in connexion with the Siemens No. 17 System, is used extensively. By the use of this principle it is possible to concentrate the traffic into a smaller number of large groups, thereby increasing the trunking efficiency of the switching system.

(*d*) Selectors in tandem are used in some instances to increase the availability of a single switching stage. This arrangement is practicable with the high speed of search of the motor uniselector, and provides 200 outlets with an 8-conductor circuit.

(*e*) Marker control principles (q.v.) are used throughout the switching scheme. The motor uniselector wipers are made to search either for a particular marked contact in the bank, the first

contact marked as free, or the first free contact in a marked section of the bank. In certain cases the motor uniselectors are controlled from the 50 c/s a.c. mains in order to obtain a hunting speed of precisely 100 steps per second. This arrangement is used for obtaining precise timing of certain relay operations in the V.F. signalling system.

(*f*) The apparatus racks are based, as far as possible, on the standard British design (i.e. 10 ft $6\frac{1}{2}$ in. high $\times$ 4 ft 6 in. wide). The motor uniselectors mount on the same centres as the relay sets (i.e. $1\frac{3}{4}$ in.) so that each shelf of the rack can accommodate either 10 relay sets or 10 motor uniselectors. Steel covers are fitted over the rear of the uniselector banks to provide protection and to minimize the accumulation of dust.

AUTOMATIC TRUNK SWITCHING IN GREAT BRITAIN

The mechanization of the trunk system in Great Britain has been the subject of close examination over a number of years. Progress in this direction may at first sight appear to be slow, but it must be remembered that there is a considerable amount of preparatory work before it is possible to introduce extensive automatic switching in a complex trunk network. Until recent years long-distance trunk circuits were provided on a "demand" basis, i.e. only sufficient circuits were provided to enable approximately 85 per cent of the total busy hour traffic to be completed within a 1-minute search period—the remaining 15 per cent of the calls being completed on a delay basis. Such a basis of provision is clearly unsatisfactory for a mechanized trunk system. During the past few years considerable additions have been made to the long-distance trunk network in order to make available sufficient circuits to provide a "no delay" service between all the more important zone and group centres.

Before it is possible to adopt automatic trunk switching, it is also essential that there should be available a satisfactory system of long-distance dialling suitable for both physical and carrier circuits. The dialling system must make it possible to dial over two, three, or possibly more links in tandem, whilst still keeping the impulse distortion within the prescribed limits for the equipment at the terminal automatic exchange. These dialling systems must be of such a type that they can be introduced at existing exchanges where accommodation may be restricted and where the power plant will supply only limited additional demands. Considerable experience has been gained during the last ten years from the use of voice-frequency dialling over direct circuits from trunk switchboards. As a result of this experience, it is now possible to design a V.F. signalling scheme which can be applied to an automatic trunk switching system and where the distortion over several links in tandem is within tolerable limits. Such voice-frequency signalling circuits are of particular application to the longer trunk routes which are worked on a carrier or co-axial basis. Recent improvements in the characteristics of electronic valves have made it possible to design V.F. receivers which are compact in size and which require a minimum of electrical energy. It is therefore possible to envisage the introduction of voice-frequency working even at small exchanges.

Coincident with the development of voice-frequency signalling techniques, considerable attention has also been paid to long-distance impulsing by direct current methods. The single-commutation d.c. impulsing scheme described in the previous chapter has a very satisfactory performance on circuits up to 100 miles in length, and provides an economical solution on the shorter trunk routes where physical conductors are available.

Since the war there has been a very considerable increase in the volume of trunk traffic which has placed a heavy strain on the existing manual trunk exchanges. The prevailing difficulties of obtaining building extensions and new buildings have added a sense of urgency to the development of a mechanized trunk switching system. At the present time the proposals for the mechanization of the British trunk network are in an advanced state of development, but it will be several years before the necessary equipment can be manufactured and installed. It is not possible at this stage to give more than a broad outline of the principles which may be followed in the design of the switching equipment and of the associated manual trunk switchboards.

Dialling Codes. At the present time there are some 6000 exchanges in the United Kingdom and it is estimated that this number will increase to some 8000 as the telephone system grows. Under a full automatization scheme, the operator at the originating trunk exchange will have to obtain access to the required exchange by dialling a number of routing digits. The simplest possible method of obtaining access to the required exchange is for the operator to dial a series of digits which will be directly applied to the trunk network in order to step the switches at the various centres to the required levels. Access to some exchanges may be obtained by the dialling of 1 or 2 routing digits, but more difficult calls may require a very much greater number of digits in order to route the

call through a number of tandem centres before reaching the required exchange. It has been estimated that as many as 15 digits in all may be required for some calls. Such calls would be exceptional, and for the majority of calls not more than 9 digits (including the subscriber's number) would be required. The following table, which has been prepared from a study of trunk dialling conditions in this country, is interesting in this respect:

No. of Digits Required	Percentage of Calls Originating at	
	Zone Centres	Group Centres
5	9	4
6	17	4
7	18	10
8	27	25
9	20	17
10	4	21
11	3	11
12	1	3
13	1	3
14	—	1
15	—	1

91 per cent of all calls from zone centres can be completed by dialling 9 or less digits. As is to be expected, the number of digits required from group centres is somewhat greater, but, even from these exchanges, 60 per cent of the calls can be completed by dialling 9 or less digits, whilst 81 per cent can be completed with 10 or less digits.

As an alternative to dialling the digits required to position the trunk switches, it is possible to introduce a system of exchange codes which could be translated into the necessary routing digits as required. A 4-digit code would cater for a theoretical maximum of 10 000 exchanges. The use of a code which is independent of the routing digits required has two very great advantages:

(*a*) The same code can be used by the operators at any exchange throughout the country, irrespective of the routing of the call.

(*b*) It allows full flexibility for the re-routing of traffic as may be considered desirable.

The absence of translation may involve the correction of the routing instructions at a very large number of exchanges when any change is made in the switching arrangements.

On the other hand, the adoption of a national numbering scheme with translation facilities adds to the cost, complexity and fault liability of the system. It would, moreover, not be practicable to introduce a uniform code dialling scheme at the outset owing to the impossibility of providing suitable translators at every exchange. It has therefore been decided that, on the introduction of the trunk automatization scheme, each controlling exchange will have its own set of routing codes, and the operator will dial all the digits required to reach the distant exchange. A national numbering scheme, with the necessary translation facilities, is envisaged as a later development.

Routing of Traffic. The main structure of the British trunk and junction network has already been described in Vol. I. Briefly, the whole country is divided into 13 zones, each *zone centre* having (with a few exceptions) routes to all other zone centres. Each zone is, in turn, divided into a number of smaller areas or groups, and one exchange, known as the *group centre*, is selected as the switching point for long-distance traffic to and from that group. There are somewhat less than 200 group centres at the moment, but it is anticipated that this number will increase to nearly 300 on completion of the trunk automatization scheme. All other exchanges are classified either as *minor exchanges*—if they have direct junction routes to the group or zone centre—or *dependent exchanges* if calls to the group centre exchange must be routed through a minor exchange. The normal routing for trunk traffic is as shown by the full lines in Fig. 714. This network of routes is the fundamental minimum which must at all times be provided in order that any exchange may be able to obtain connexion to any other. Such junction and trunk groups are therefore known as *basic routes*.

In addition to the basic network, additional circuits, known as *auxiliary routes*, are provided wherever the volume of traffic can justify such provision. The provision of a direct auxiliary route between two exchanges is influenced by a number of factors. Apart from the speed of service to the subscriber, the prime consideration is the question of cost. A direct auxiliary route is economic only when the cost of handling the traffic over that route, together with the annual charges of the line plant and terminal equipment, is less than the cost which would be incurred if the traffic were routed through the normal basic network. In a manual trunk switching scheme, the time required by telephonists to establish calls has a material influence on the economics of any particular case. Under automatic switching conditions, however, the number of telephonists required and the time occupied by the telephonist for the establishment of the call are substantially the same whether the traffic is handled over a direct auxiliary route or indirectly through the

basic network. The economics of route provision are almost wholly related to the annual charges for the necessary lines and the associated signalling and switching equipment.

With manual switching it is usual to consider the provision of a direct auxiliary route between two exchanges when the traffic reaches 16 calls in the busy hour. It is probable that with automatization a higher volume of traffic will be necessary before an auxiliary direct route can be justified. In any particular circumstances, it is necessary to know:

(*a*) The total annual charges per circuit of the proposed direct auxiliary route.

(*b*) The number of such circuits required to carry the traffic.

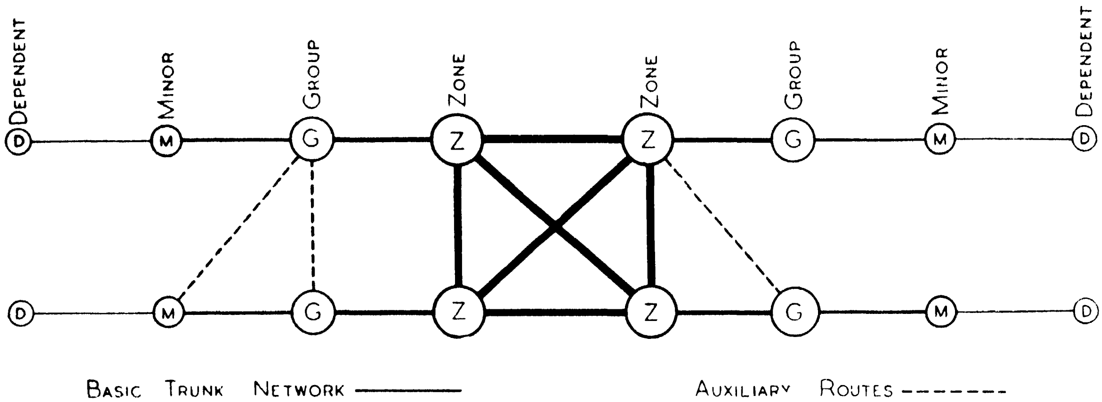


FIG. 714. NORMAL ROUTING OF TRUNK TRAFFIC

(*c*) The annual charges per circuit for each link on an alternative route through one or more tandem switching centres.

(*d*) The number of additional circuits which it will be necessary to provide on each link of the tandem route.

A direct route can be justified only if the product of (*a*) and (*b*) is less than the sum of the products of (*c*) and (*d*).

The probable reduction in the number of auxiliary routes consequent upon automatization will tend to increase the volume of traffic passing through the automatic switching equipment at the larger zone and group centres. A heavy concentration of automatic trunk switching equipment at such centres makes the network more vulnerable, and the effect of a breakdown is more serious. Moreover, accommodation in the centre of large cities is expensive and is hard to find, and the standard of maintenance tends to suffer where the equipment is concentrated into large units. Trunk automatization mav make it desirable to introduce additional zone centres or, alternatively, to arrange for ***sub-zone centres***. Such a sub-zone would comprise a number of adjacent groups, and one of the group centres (normally the largest) would serve as the sub-zone centre for the switching of traffic to and from its component groups. Thus, a group centre in a sub-zone would have a basic route to its sub-zone centre in addition to the normal route to its main zone centre. By this means, traffic to certain other zones and groups could be routed direct from the sub-zone centre (if direct circuits were provided) instead of via the main zone switching point.

Switching Facilities Required. In order to provide a country-wide system of trunk switching, automatic equipment must be provided at each zone and group centre. This equipment must provide for the switching of three main categories of long-distance traffic, i.e.:

(*a*) Outgoing traffic originating from the subscribers in the local group. This traffic must necessarily be passed through an operator at the originating trunk exchange who will dial or key up the routing code and the required subscriber's number. This operator is also required to prepare a ticket for accounting purposes.

(*b*) Through traffic from distant centres which is switched on a tandem basis to other trunk centres.

(*c*) Terminating traffic incoming from distant centres and intended for subscribers on the exchanges within the group.

At some of the smaller group centres it may be unnecessary and uneconomical to provide a separate trunk switching train. In such cases the local automatic exchange equipment can probably be used for long-distance switching. In the larger exchanges the volume of trunk traffic will usually

be sufficient to justify a separate *trunk tandem exchange*, which will work in conjunction with the trunk switchboard and the local automatic network. The zone and group centres may therefore comprise four main units, viz.:

The manual board.
The local automatic exchange.
The repeater station.
The automatic trunk tandem exchange (where the local automatic selectors cannot be used for trunk switching).

Possibly the best arrangement is for all four units to be located on one site, but, if the available accommodation does not permit of this and some segregation is necessary, it is preferable that the trunk tandem should be installed in the same building as the local automatic exchange. If circumstances make it necessary to locate the trunk tandem exchange on a different site from that of the local automatic exchange, it is desirable to associate the terminations of the trunks and junctions with the trunk tandem exchange, thereby minimizing transmission losses and facilitating bothway working.

In some circumstances there may be advantages in dividing the trunk tandem exchange into two sections. The first section will handle traffic originated through the manual board, whilst the second section will deal with incoming and through traffic. By this arrangement it is possible to give delay and congestion announcements on incoming and through calls whilst allowing the local operator access to the route through the second section of the exchange. With very large routes it may be possible to obtain economies in the quantity of switching plant by dividing the route into two parts, one for through traffic and the other for terminal traffic. These two component routes would be terminated on the trunk tandem exchange and local automatic exchange respectively.

Cordless Switchboards. In the past, the design of manual trunk switchboards has been largely determined by the necessity of providing a complete multiple of all the trunk and junction routes and of the "0" level circuits from the local automatic network. With the introduction of mechanized trunk methods, the operator can obtain access to any desired route via the banks of the trunk selectors, and it is no longer necessary to provide for the appearance of each individual circuit on the manual board. This in turn makes it possible to design a trunk switchboard which will provide a greater degree of convenience and comfort to the operator. The cordless type of switchboard has many advantages and this principle will be adopted on the boards which are in course of design for the British system. In this connexion it should be pointed out that, whilst cordless trunk switchboards are a desirable part of the trunk mechanization scheme, it is not necessary (nor indeed practicable) to convert all trunk exchanges to cordless working on the introduction of the automatic trunk switching scheme. For some years there will be a number of zone and group centres with switchboards of the present standard sleeve control type.

A detailed study has been made of the various cordless switchboards designed for use at Capetown, Melbourne, Amsterdam, Philadelphia, Stockholm, etc. As a result of this study it is recommended that the switchboard position should resemble an office desk or table so as to give the impression of clerical rather than of factory working conditions. Some slight slope or raised feature will be necessary in order to make the supervisory and other signals readily visible to the operator, but it is considered that any such slope should be kept to a minimum. Considerable importance has been placed upon the physical design of the position, which should be suggestive of office or even of domestic furniture rather than that of a factory work table. Particular attention will also be paid to the colour and finish of the switchboard. (A limed oak colour with a green fibre keyshelf, or a finish in two shades of brown, are favoured.)

The new switchboards will have a width of the order of 33 in. as compared with 27 in. of the present standard sleeve control switchboards. The keys on each position will be arranged so that the movements of the operators' hands are kept to a minimum, and the various keys, etc., will be coloured to simplify operating procedure. The new positions will also provide a larger amount of writing space than is possible on switchboards of the cord type. The writing surface will be approximately 10 in. in depth and will have a surface which is smooth and is not cold to the touch.

The absence of cords and pulley weights makes it possible to design a switchboard where the keyshelf is at such a height that an ordinary chair can be used. It is also possible to provide considerably more foot space and to abandon the use of foot rails.

Fig. 715 gives a general view of an experimental model position. The large amount of writing space, the comfortable working position of the operator, and the attractive general design of the switchboard will be noted.

Lay-out of Manual Switchroom. Fig. 716 shows a specimen lay-out of a trunk switchroom with

85 positions of the cordless type. The absence of multiple cables makes it possible to arrange the positions in comparatively short suites across the room, thereby obtaining material advantages in respect of light, ease of supervision, and so on. In this particular case the presence of stanchions down the centre of the switchroom makes it desirable to limit the length of each suite to 5 positions. The suites are arranged in pairs, back to back, with a distance of some 7 ft between the front edges. A narrow gangway, approximately 2 ft to 2 ft 6 in. wide between the backs of the positions facilitates supervision and maintenance. Since the main access to the positions is from the side gangways, the space between consecutive pairs of suites can be reduced to about 8 ft without difficulty. Satisfactory access could be obtained by somewhat smaller dimensions between suites, but the number of positions which could be accommodated in a given switchroom depends largely upon the cubic capacity of air which must be made available for each occupant of the room. Nothing is to be gained, therefore, by decreasing the spacing between units.

Distribution of Traffic. It is very desirable that incoming calls to the trunk switchboard should be dealt with in the order in which they originate. This, in turn, necessitates the provision of switches which will give access to the cord circuits on every trunk position. In a large exchange this ideal scheme is not practicable due to the limited availability of automatic selectors. We have seen that in the Melbourne scheme the positions are divided into "fields" of 28 positions, each field being served by a separate group of distribution switches. There are two such distribution groups for demand traffic at Melbourne, each group having its own queue of waiting calls. The disadvantage of dividing the exchange into a number of fields, each served by a separate queue, is that the service may vary between one field and another due to fluctuations in the traffic, unequal staffing of the

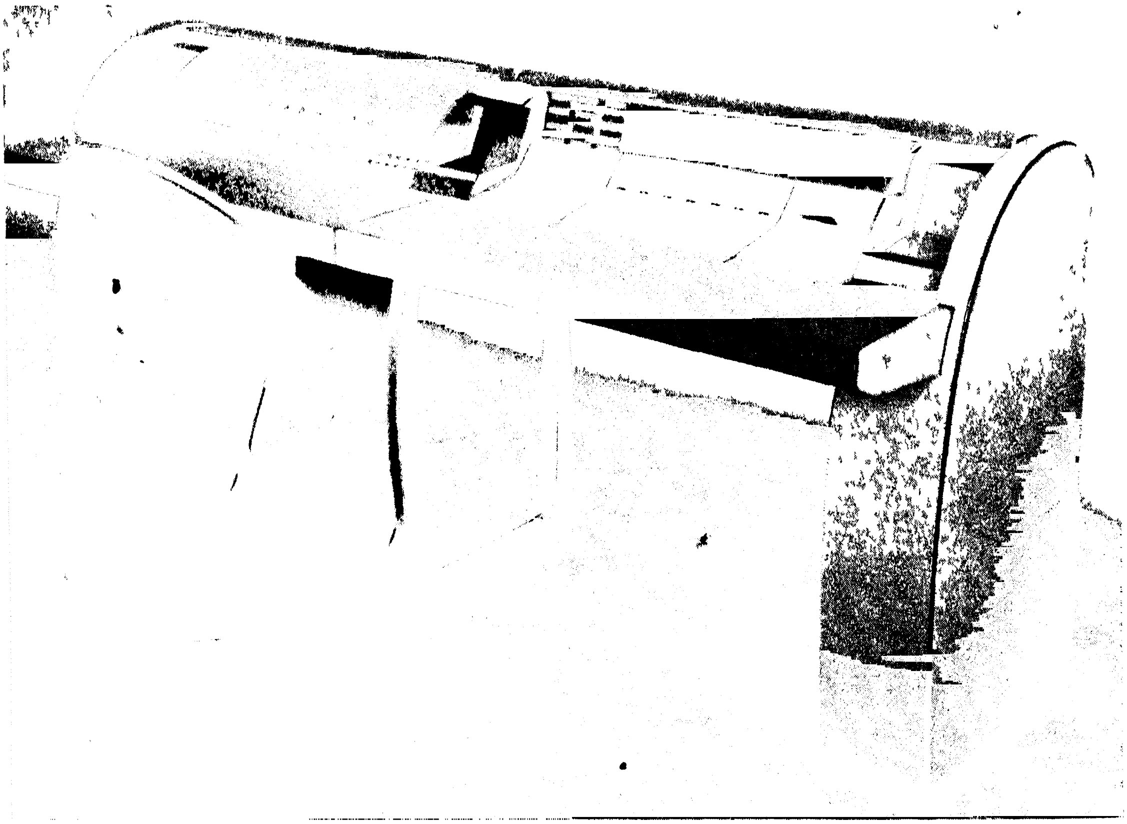


FIG. 715. EXPERIMENTAL MODEL OF CORDLESS TRUNK SWITCHBOARD

fields, etc. These variations may give rise to widely different speeds of answer, thereby defeating to some extent the purpose of the call queueing system. In the Melbourne scheme a reasonable balance between the two distribution fields is obtained by the use of link positions which can accept calls from either of the two queues depending upon the traffic conditions in each distribution system. These link positions can thus be used to assist the field which has the greater number of calls in the queue or, alternatively, it can assist the distribution field which contains calls which have been waiting the longest time.

A careful study of the operating call values in Great Britain has indicated that 7 connecting circuits will be required per demand position. If 200-outlet distribution switches are used, each distribution group will cater for 25 demand positions, each with 7 connecting circuits. This absorbs 175 of the available 200 outlets, thereby leaving the remaining 25 positions to provide for the queue (and for spare contacts for testing, etc.). The use of link positions still further reduces the number of demand positions which can be served by one group of distribution selectors. Moreover, link positions somewhat complicate the trunking and switching arrangements, and add to the cost of the system.

The distribution arrangements recommended for the British system are illustrated in Fig. 717. Each incoming demand circuit is terminated on a 50-point uniselector of the normal ratchet and pawl type. These line switches are arranged in groups and the circuits are allocated to the groups in such a way as to equalize as far as possible the traffic in each group. The outlets from the line switch groups are taken to a grading frame, the outlets of which give access to the various distributor groups. The demand distributors are motor uniselectors with an availability of 200, 175 of the outlets giving access to a field of 25 demand positions (7 connecting circuits per position). The remaining contacts are connected to a queue control circuit which determines the order in which calls are permitted to enter free positions. For various reasons it has been decided that in future no exchange shall exceed 100 controlling positions. If the trunk switching centre requires more than this number of positions, then it is necessary to provide two or more separate and distinct manual switchrooms. Thus, in the largest exchange there will be 4 fields each of 25 positions, and 4 groups of distributors, each with its separate queue, to serve these positions.

The volume of traffic entering each distribution field is balanced as far as possible by the allocation of the distributors to the outlets of the grading, and by the arrangement of the line switch groups. This balance of incoming traffic does not, however, ensure comparable speeds of answer on the several groups, since no allowance can be made for the number of staff on duty, the relative efficiency of the operators, and so on.

The provision of link positions is not favoured in

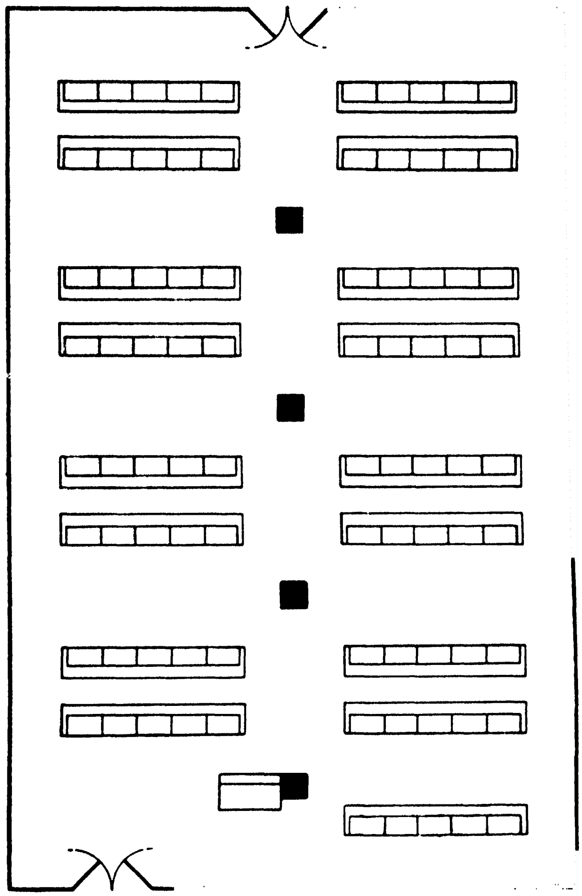


FIG. 716. TYPICAL LAY-OUT OF LARGE TRUNK EXCHANGE WITH CORDLESS POSITIONS

view of the reduction in the availability, and the circuit complications. It is proposed to obtain approximate equality in the speed of answer by the adoption of a system of time control which will be automatic in action. All calls are timed (to an accuracy of $\pm$ 1 sec) from the moment they enter the queues. As soon as the waiting time of any call exceeds 15 sec, the queue in which that call is held is closed, and all further calls are distributed amongst the remaining queues. When a queue has been closed in this way, it is not reopened until

all calls which have been waiting for as much as 15 sec have been dealt with. If the traffic grows to such an extent that all queues except one are closed the time control is automatically changed from 15 sec to 30 sec, and all queues are reopened to traffic. If any queue now contains calls which have been waiting for 30 sec, this queue is closed calls have been worked off, when the reverse process of time control operates (i.e. the time control is successively shifted from 120 sec in steps of 15 sec until it is again operating at 15 sec delay).

It should be noted that the above scheme does not produce complete equality in the times of answer of calls passing through the different

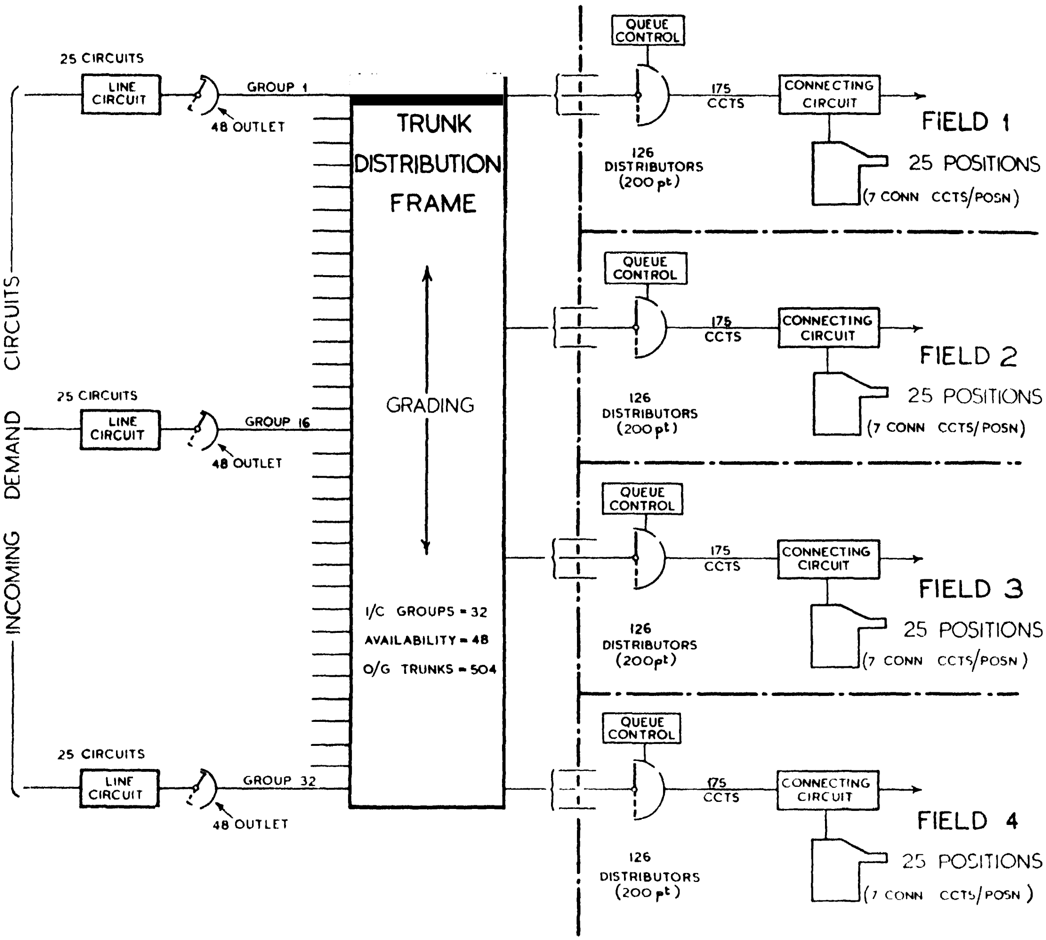


FIG. 717. TYPICAL DISTRIBUTION SCHEME FOR LARGE EXCHANGE

as before, and the traffic is diverted to the other queues.

If the service continues to deteriorate, the queues are closed one by one in this way until only one field is open. The time control now changes from 30 to 45 sec, and all queues are opened again for traffic. This process may continue until the control is operating at 120 sec. If this time of answer is reached in all queues together, the complete system is closed and engaged tone is returned to callers. This condition persists until the delayed queues, but it does control the variations within reasonably narrow limits. The time control scheme is, of course, not required on single field exchanges (i.e. exchanges with up to 25 positions).

From theoretical considerations and from records of the speed of answer at a number of representative exchanges, it has been decided that each queue (which serves a field of 25 positions) shall accommodate 20 calls. If any queue becomes full while there are vacancies in the other queues, the circuit arrangements are such that further calls will

pass to the queues with vacancies (subject, of course, to the time control requirements). If a call originates when there are no free places in any of the queues, engaged tone is returned to the caller.

At multi-field exchanges, arrangements are provided for the concentration of the traffic on to one field under night conditions. Each position is automatically engaged by the withdrawal of the operator's plug so that the whole field is placed out of service when the last operator withdraws her instrument plug. Facilities will also be provided for the closure of a field by the section supervisor, so that a few operators can be left on the positions to complete any calls which may be waiting in the queue prior to the closure of the field. Generally speaking, the incoming and monitorial positions will be concentrated within their own distribution systems in the same way as the demand positions. In special circumstances, however, it may be desirable for a few positions to handle all three types of traffic, in which case it may be possible to provide three separate groups of connecting circuits on the concentration positions.

The design of the grading between the line switches and the distributors must ensure that there is equal access to all fields from the line circuits so that, as concentration proceeds (and the fields are closed down) the symmetry of the grading is maintained. During such concentration, the availability of the line switches becomes progressively less and the traffic offered to each remaining field is correspondingly reduced. In the extreme case with only one field working, the traffic offered may not be sufficient to justify a full complement of 25 operators. It is necessary, therefore, to exercise some control of the staffing arrangements as concentration proceeds in order to ensure that sufficient fields are kept open to enable the traffic to reach the operators.

Establishment of Calls. Fig. 718 shows the general arrangements of the position connecting circuit. Each connecting circuit is provided with two uniselectors (of the standard ratchet and pawl type) each of which gives access to 1st trunk selectors. One of these uniselectors is associated with the calling side of the connecting circuit, whilst the second uniselector serves the answering side of the connecting circuit. Ordinarily incoming calls reach the connecting circuit via the demand distributor. The operator ascertains the exchange and number required, and sets up the necessary routing and numerical digits by means of a key-strip. There is one individual sender per position and, on completion of keying, the sender transmits the appropriate trains of impulses via the "calling side" uniselector to 1st and subsequent trunk selectors.

In some cases it may be necessary to set up a revertive connexion to the calling party. The operator can key up the number of the called subscriber and any routing digits which are necessary to establish a call to him. By the depression of the "send answer" key, the position sender transmits the impulse trains via the "answering" side uniselector and the subsequent trunk or local selectors to establish the connexion to the calling party. When the sender becomes free, the operator sets up the forward side of the call (i.e. to the called party) in the manner

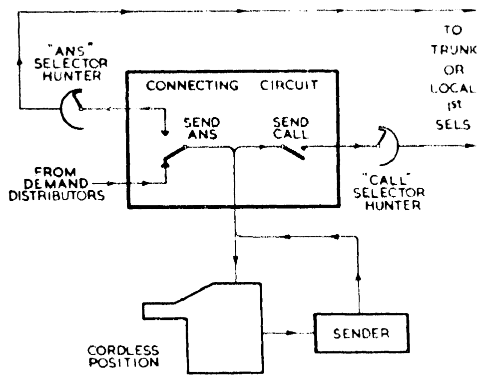


FIG. 718. GENERAL ARRANGEMENTS OF CONNECTING CIRCUIT, SENDER, ETC.

already described, and thereby establishes the connexion.

We have seen earlier in this chapter that the number of digits required to establish a call may vary from 5 to approximately 15, depending upon the routing of the call. It would be uneconomical to design a position sender which is capable of giving 15 consecutive routing digits at one setting. It has therefore been decided to limit the number of impulse trains from the sender to 12 and, on the exceptional calls which require more than this number of digits, it will be necessary to take the sender into use for a second time for the remaining digits.

Position Equipment. Fig. 719 gives a suggested lay-out of the equipment on a demand position. Provision is made for 7 cord circuits, each of which has an individual speak/monitor key and a chargeable time clock with its associated control key. There are 5 lamps associated with each connecting circuit, and these are mounted behind a translucent panel so that the lamps, when alight, shine through suitably lettered stencils. There

are 2 circuit engaged lamps, one to indicate that the call is from an ordinary subscriber, and the other that the call is from a coin-box line. The appropriate lamp is caused to glow immediately a call is extended to the connecting circuit from the distributor. The engaged lamp remains alight until the call is finally released by the operator. On reverted calls, the "ordinary call" lamp glows automatically when the sender is taken into use, but if the call is reverted to a coin-box, the operator can light the coin-box lamp (instead of the ordinary lamp) by momentarily depressing the REV. C.B. key. Two further lamps are provided per cord circuit to give the standard calling side and answering side supervisory signals. The 5th lamp is the time check lamp, which glows after 9 min on ordinary calls, or flickers after every 3-min period on coin-box calls.

It is proposed that the "connect answer" key, which opens up the position to receive a call from the queue, should be of similar design to the space bar of a typewriter and should be located in front of the connecting circuits.

The digit keys are arranged in two groups of 5, and are mounted at the right-hand side of the position together with a group of 3 sender control keys (send-call, send-answer, and sender-finish). A 4th key (LOC) is associated with the sender control keys, and provides for the switching of the call to a local switching train instead of to the normal trunk switching train (see later). A Sender Taken lamp is mounted in the supervisory panel immediately above the keystrip to indicate that the sender is engaged and cannot be used again until it has finished pulsing out. The remaining common keys of the position are grouped on the left-hand side and provide:

Speak answer/speak call for speaking on the answering and calling sides independently.

Ring answer/ring call for ringing on the answering and calling sides independently.

Release answer/release call for releasing separately the answering and calling sides of the connexion.

A *coupling* key which is combined with an order-wire key to the R.R.Q. position.

A *call supervisor* key.

A lamp is provided on the left-hand side of the display panel to indicate when the operator has pre-set her position in readiness to accept the next call. (A position is normally pre-set by the

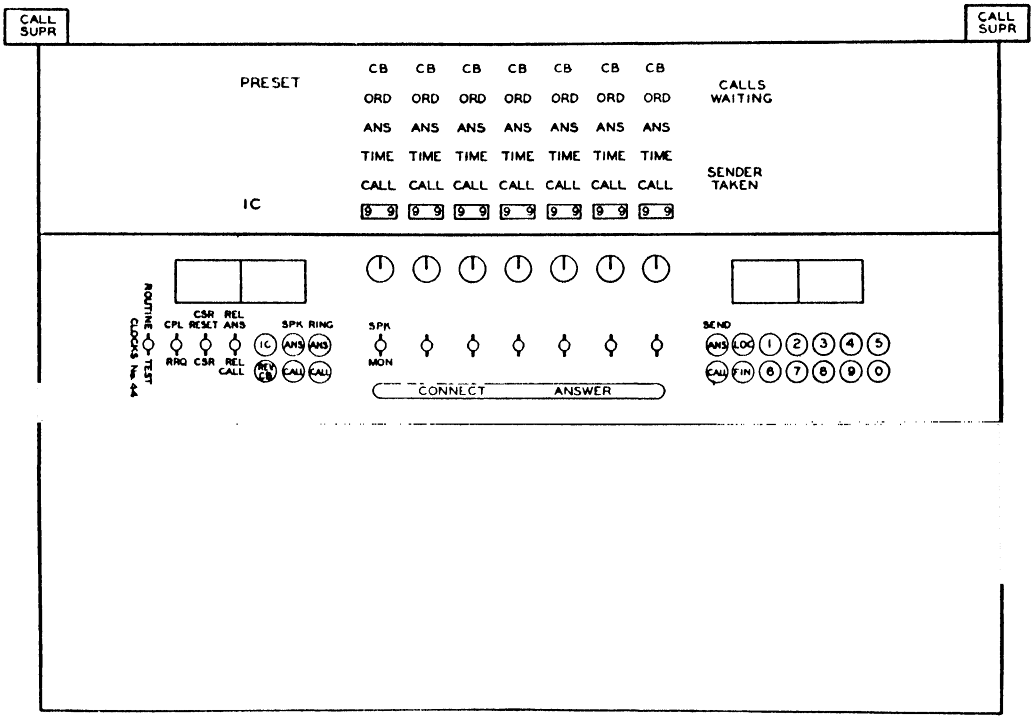


FIG. 719. LAY-OUT OF EQUIPMENT ON DEMAND POSITION

operation of the speaking key of a free connecting circuit and by the operation of the position connect answer key.) In a comparable position on the right-hand side of the display panel is a lamp which, when lighted, illuminates a stencil indicating that there are calls in the queue awaiting answer. (Note that no indication is given to the operator of the number of calls in the queue or of the waiting time.)

Alternative Routing. Call Storage and Delay Working. It is the intention that no special provision shall be made to give automatic alternative routing in the event of congestion on the main route. Such facilities require additional equipment and are not considered necessary with the more generous provision of line plant which is planned. It will be recalled that call storage facilities are included in the Melbourne scheme. By means of this facility the operator can key up the desired routing, and, if all circuits on the route are engaged, the call is held in a special storage circuit. Facilities are provided whereby, when a circuit becomes free, a signal is given to all operators who have calls in storage for that particular route. The operator who accepts the call is switched to the free circuit. Whilst the idea of call storage is attractive from an operating point of view, there are certain difficulties when it is applied to routes which carry multi-link traffic and where it is necessary to grade the outlets of the trunk selectors. It has therefore been decided not to include this facility in the British scheme.

Although the number of trunk circuits to be provided on the introduction of automatic switching will be sufficient to give a no delay service under normal everyday conditions, it is necessary to make provision for abnormal circumstances, such as cable breakdowns, etc. Such conditions should be of comparatively rare occurrence and will have only a temporary effect on the service. It is doubtful, therefore, if the provision of expensive equipment to cater for delay working is justified. It is proposed that free access to all routes should remain available to all operators at all times. If it is necessary (exceptionally) to place any route in delay working, the demand operators will be instructed to refrain from using the routes concerned. Some form of delay posting board will probably suffice to indicate any routes which are in delay working. This board will, of course, have to indicate the routing digits of all circuit groups which are in delay.

Delay working on distant trunk groups (i.e. at an intermediate switching point) can be indicated to originating operators by the provision of a delay announcement on the appropriate selector level at the intermediate exchange. On receiving such an announcement, the controlling operator can either re-book the call or try again at a subsequent time.

Subscribers' Emergency Service. Special arrangements must be made for obtaining immediate access to an operator on emergency "999" calls. The "999" levels of the local network will be trunked out to special distribution switches which give access to a number of selected positions in the concentration field. The circuit arrangements will be such that any emergency call enters at the head of the queue in the particular field where it appears. The first free operator will take the call in the same way as she would an ordinary call, and she will receive a lamp indication to confirm that she has in fact answered an emergency call. This lamp indication will also be visible to the section supervisor to enable her to identify the position at which the call has been answered.

Traffic and Staff Control. In the Melbourne trunk exchange a special "Delay Supervisor's Position" is provided to give a wide range of facilities for observing the traffic on the exchange and for controlling the allocation of staff to the various switchboard suites. Each operator is also given a lamp indication of the number of calls in the queue and of an excessive waiting time.

It is considered sufficient in the British system to provide the operator with a simple lamp indication that there are calls awaiting attention in the queue. More detailed information will be available to the section supervisor in respect of positions for which she is responsible. It is recommended that a display be provided for each field to indicate:

(*a*) The number of calls in the queue.

(*b*) The point at which the time control is operating.

(*c*) Whether or not the queue is open to further calls.

Further and more complete information will also be provided on the Chief Supervisor's desk. The following facilities are proposed:

(*a*) A queue display of the barometer type to show the number of calls waiting in each of the queues serving the exchange.

(*b*) A position staffing indicator to show which positions in the various fields are staffed.

(*c*) A time control display per field to show the stage at which the time control of distribution is being applied.

(*d*) A field open indicator to show which fields are open and which are closed to traffic.

(*e*) A speed of answer alarm to operate when the time of answer exceeds a predetermined value.

(The value can be varied by the officer in charge to suit the prevailing conditions.)

(*f*) An engaged tone alarm to operate when the engaged tone is being returned to callers under "queue full" or other conditions.

Routing Information. With the proposed mechanized trunk system, it will be necessary to supply each operator with details of the code digits which must be used to establish a call to any required destination. In some cases the number of code digits will be comparatively large, and any system of verbal enquiry by the operator will tend to result in errors. It is therefore desirable that as complete routing information as possible should be available to each operator in visible form, verbal reference to a central routing information point (R.R.Q.) being kept to a minimum.

The visible index files as used on the present sleeve control trunk switchboards can be adapted for use with the mechanized trunk scheme, but it is possible that some better method may be found. Investigations have been made into the use of various forms of display utilizing cathode-ray tubes, micro-film or lamp displays of the C.C.I. type. Most of these are, however, rather complex and require a considerable quantity of equipment. There are various proprietary devices consisting of cards mounted on drums, or entries on a long roll of paper which can be passed under a suitable window.

Alternative Trunking Arrangements. The conditions at each trunk centre vary considerably, and hence a trunking scheme which may be economical at one place may be unsuitable for use at another. Figs. 720 to 723 indicate four possible alternatives to provide the most economical switching scheme in different circumstances.

With the scheme of Fig. 720 the connecting circuit selector hunters are arranged to give access either to the local switching train or to the trunk tandem exchange in response to a discriminating signal from the operator's keystrip. With the "local" key normal, the selector hunter automatically seizes a 1st trunk selector, but, if the key is operated, the selector hunter searches for and seizes a 1st selector in the local automatic exchange. This scheme segregates the local traffic from the trunk traffic, thereby reducing the number of 1st trunk selectors required and making more outlets of these selectors available for outgoing trunk routes. On the other hand, the operating procedure is made slightly more complex in order to provide the necessary discriminating signal.

Fig. 721 shows an alternative scheme in which access to the local automatic network is obtained via the 1st trunk selectors. This increases the number of 1st selectors required, and necessitates an additional digit on local traffic. On the other hand, the operating procedure is uniform on calls

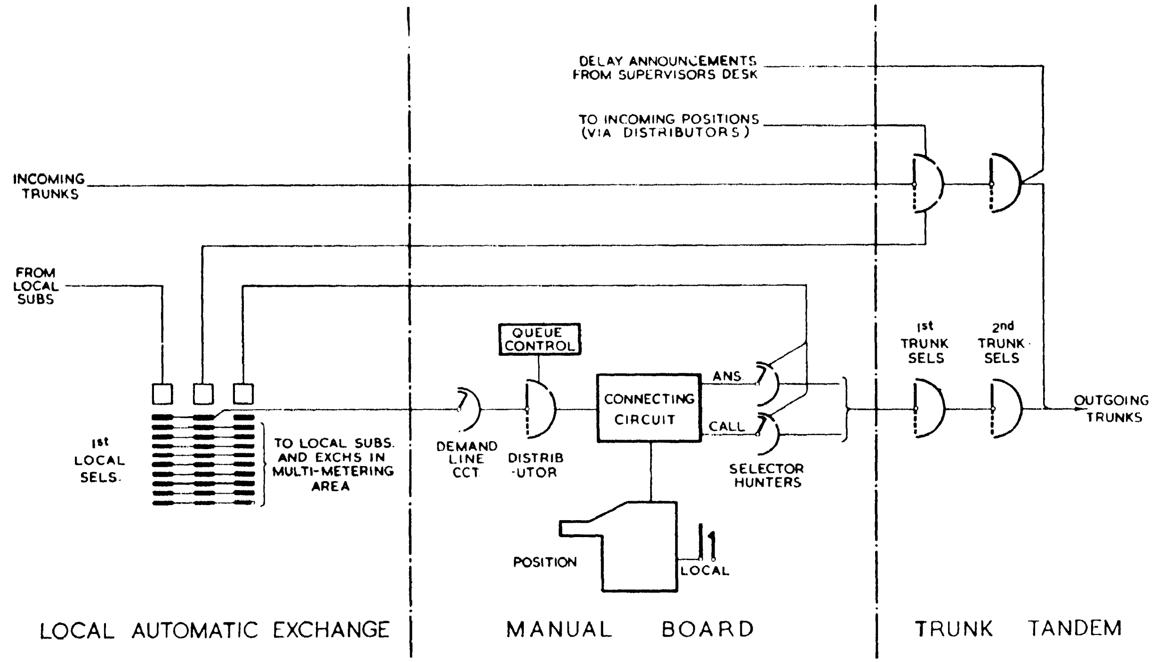


Fig. 720. Typical Trunking Scheme with Key Discrimination for Local Traffic

of all types. As an alternative arrangement, the selector hunters could be arranged to give access to local 1st selectors, and a level of the latter could be allocated to route calls to the trunk tandem exchange. This, of course, requires an extra digit on all trunk calls.

In the arrangement of Fig. 722, a special group of 1st selectors is associated with the manual board. The outlets of these selectors can be divided into three groups, viz.:

A group of trunks leading to local 1st selectors.
A group of trunks to 1st trunk selectors.
One or more groups of trunks to cater for direct routes from the manual board to adjacent exchanges, etc.

This arrangement is particularly suitable for very large trunk exchanges.

Fig. 723 shows a possible trunking scheme at a small group centre where it is uneconomical to provide a separate trunk tandem exchange. The selector hunters now give access to special manual board 1st selectors in the local exchange. Level 1 of these selectors is trunked to a further stage of selectors, the levels of which give access to the various trunk routes.

In each of the trunking schemes, the trunk tandem equipment is divided into two main sections. One section caters for the traffic originated through the local trunk switchboard, whilst the second section provides for terminating traffic from distant centres and for through switching.

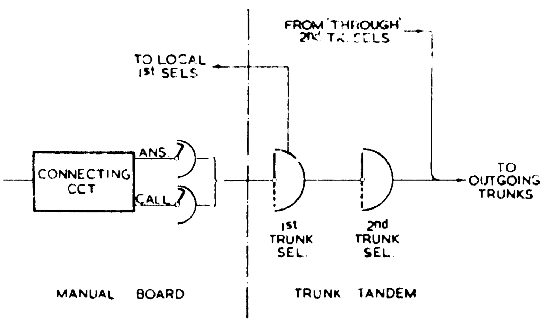


FIG. 721. ALTERNATIVE METHOD OF OBTAINING ACCESS TO LOCAL SELECTORS OR 1ST TRUNK SELECTOR BANKS

This segregation is desirable so that, if any outgoing route is placed under delay working, it is possible to give a delay announcement to distant trunk operators whilst still providing access to the operators at the local manual board.

4-wire Switching. Trunk tandem exchanges can be designed to provide switching on a 4-wire basis or on a 2-wire basis. The former requires additional conductors, wipers, and contact banks throughout the switching train but, on the other hand, it avoids the loss in the balancing network which always occurs when a 4-wire circuit is converted to a 2-wire circuit. Moreover, 4-wire switching

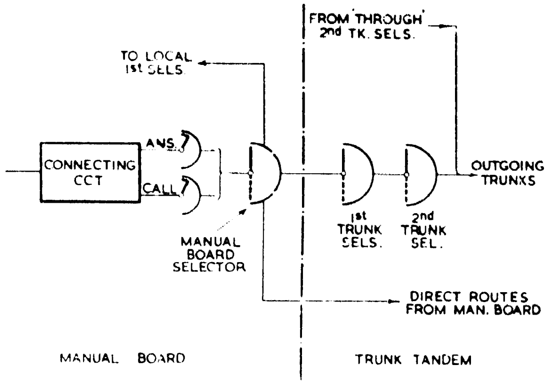


FIG. 722. TRUNKING SCHEME WITH SPECIAL GROUP OF 1ST SELECTORS ASSOCIATED WITH MANUAL BOARD

makes it possible to place the V.F. receiver in the appropriate signal channel where it is less subject to speech interference from the opposite transmission path.

The greatest problem in the adoption of a 4-wire switching scheme occurs when 4-wire circuits are to be connected to 2-wire circuits, or vice versa. One possible scheme is to convert all 2-wire circuits into 4-wire circuits by the provision of hybrid transformers where the 2-wire circuits enter the switching train. This may complicate the signalling arrangements on the 2-wire circuits and introduces a 3 db transmission loss.

Bothway *v.* Unidirectional Circuits. Generally speaking bothway working of the circuits on any route increases the flexibility during periods of directional traffic fluctuations and under breakdown conditions. It also results in a greater average traffic carrying capacity per circuit. On the other hand, bothway circuits complicate the design of the switching and signalling equipment and add to the cost and fault liability of the terminal apparatus. Bothway working also increases the risk of failure due to the simultaneous seizure of the circuit from both ends.

Very small groups of junctions or trunk lines are invariably worked on a bothway basis, but on larger groups it is usual to provide a mixture of unidirectional and bothway circuits to provide the best working conditions. A group of, say, 39 circuits on a particular route is, under manual switching conditions, normally divided into 2 unidirectional groups each of 15 lines plus a further

9 circuits operated on a bothway basis. Larger groups of trunks usually have 10 bothway circuits and the rest of the lines are worked as unidirectional circuits.

In an automatic trunk switching system where the lines are terminated on the banks of automatic selectors, some complications arise when it is necessary to introduce grading at one or both ends of the route. The problem is illustrated in Fig. 724. It is assumed, for purposes of illustration, that a trunk group consists of 22 bothway circuits between 2 exchanges X and Y. For simplicity a 10-point grading is shown. If it is assumed that the total traffic is "A" T.U. and that this traffic originates equally from the 2 exchanges, then the grading at each end must carry a traffic of $A/2$ T.U. The grading arrangements at each end will be as shown at A (Fig. 724). On the assumption that all the circuits are bothway, the total traffic offered to each circuit in the group is equivalent to that given by a single 4 group grading which is offered a total of A T.U. (grading B). If the traffic in each direction is equal, then the efficiency of the trunking scheme shown at B is exactly the same as the arrangement shown at C. Thus, although the whole of the 22 trunks are worked on a bothway basis, the traffic carrying capacity is no greater than if the trunks were arranged as 2 groups of 9 unidirectional lines plus 4 lines which are accessible from both exchanges, i.e. bothway circuits. The 4 bothway circuits are the lines which are connected to the full commons of the gradings at both ends of the circuit. It follows, therefore, that, when it is necessary to adopt grading, the group is at its maximum efficiency when the number of bothway circuits is equal to the number of full commons on the gradings.

Generator Signalling Circuits From Selector Levels. The complete automatization of the trunk network will take some years to complete. Ultimately, any originating trunk operator will be able to dial any subscriber in the system, but this will not be possible until long-distance d.c. or V.F. equipment is available on all routes. In the meantime there are material service advantages in providing automatic access to the terminal automanual switchboard during the interim period before full dialling facilities are available. With this idea in view, generator signalling circuits have been introduced which can be used from trunk selector levels in order to give access to distant sleeve control manual exchanges. These circuits will be required for a comparatively limited period, and have therefore been made as simple as possible. The scheme merely provides for the transmission of a long pulse of ringing current (or of the correct d.c. signalling conditions) when the circuit is seized by a trunk selector. An answering supervisory signal is returned immediately on seizure, and the circuit is arranged so that the supervisory signal is removed if the incoming manual operator recalls. No provision is made for guarding the outlets on the selector level during the clearance of a previous call at the manual board. There are

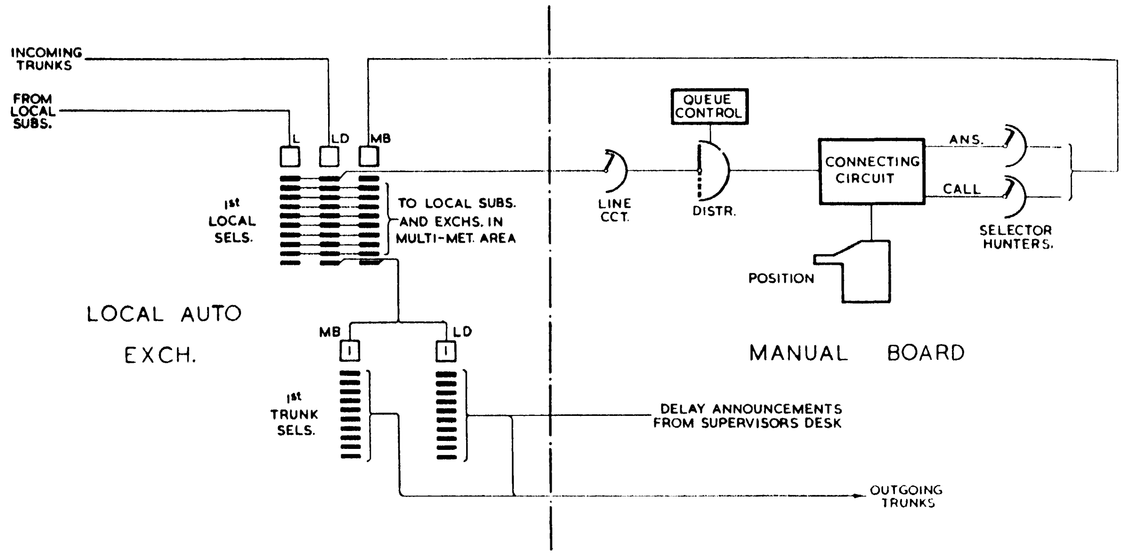


FIG. 723. TYPICAL TRUNKING SCHEME AT SMALL GROUP CENTRE EXCHANGE

also no special arrangements to prevent follow-on calls which may occur prior to the clearance of a preceding call.

Fig. 725 shows the selector level circuit at the trunk switching centre. Relay *A* operates to the calling loop and, as usual, operates relay *B*. *B*4 disconnects the terminating impedance, whilst *B*2 connects relay *PA* to the interrupted earth supply (0·75 sec earth every 1·5 sec). Relay *PA* operates to the first earth pulse, and at ***PA*1**

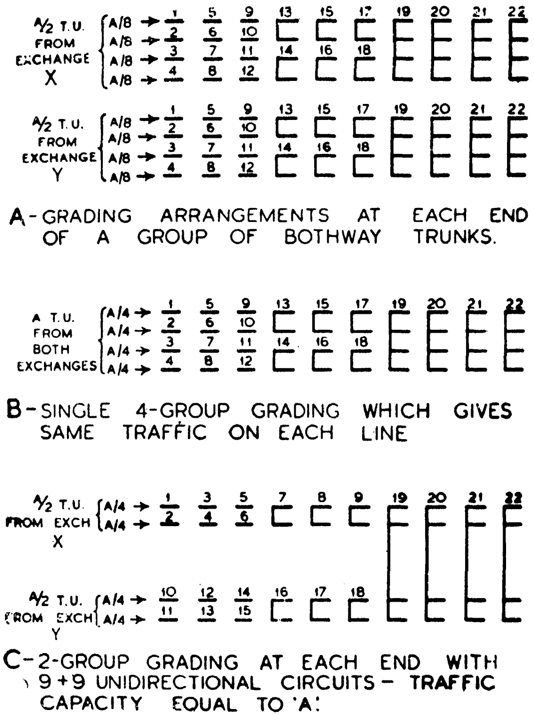


Fig. 724. Typical Grading Arrangements with Unidirectional and Bothway Trunk Circuits

prepares a circuit for relay *RR*. At the termination of the earth pulse, *RR* operates in series with relay *PA*. Contacts ***RR*1** and ***RR*2** connect ringing current to line, whilst ***RR*4** switches the interrupted earth supply to the second coil of relay *RR*. After a further 0·75 sec, the next earth pulse operates relay *PB* and provides a holding circuit for *RR* over the second coil. ***PB*3** now releases relay *PA*. 0·75 sec later, the earth is again disconnected, thereby releasing relay *RR*, and contacts *RR*1 and *RR*2 disconnect the calling signal from the line. Ringing tone is now returned from the distant incoming relay set until such time as the terminal exchange operator answers.

The incoming operator can recall the originating exchange by operating the ring key of her position

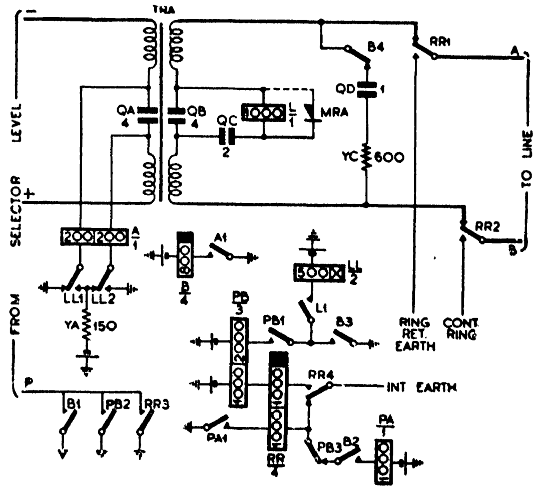


Fig. 725. Outgoing Generator Signalling Circuit Suitable for Use on Trunk Selector Levels

circuit. This causes the application of ringing current back to the trunk switching centre, to

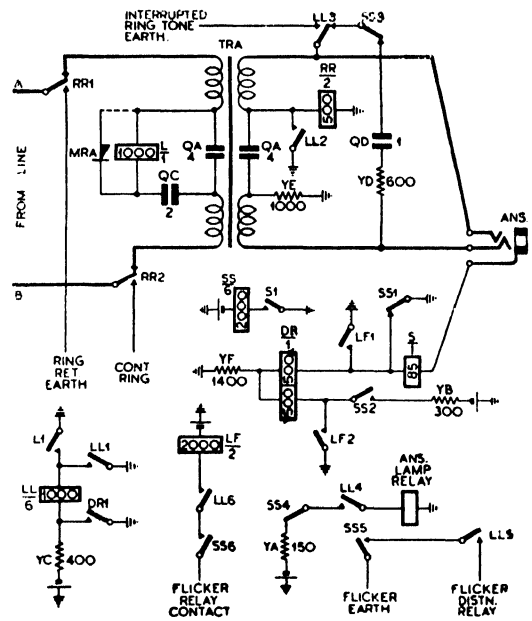


Fig. 726. Incoming Termination of Generator Signalling Circuit

operate relay *L*. ***L*1** in turn operates relay *LL*, and contacts ***LL*1** and ***LL*2** effect the normal supervisory reversal backwards.

Fig. 726 shows the incoming termination of the generator signalling circuit. Relay *L* operates to the pulse of ringing current on seizure, and at ***L*1** operates relay *LL*. ***LL*2** and ***LL*3** return ringing tone to the caller, and also disconnect the line

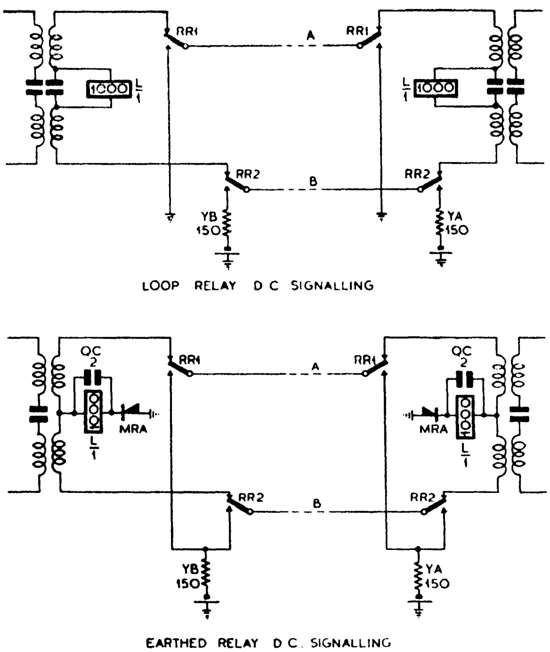


FIG. 727. ALTERNATIVE CIRCUIT CONNEXIONS TO GIVE TWO FORMS OF D.C. SIGNALLING

terminating impedance. ***LL*4** operates the answering lamp relay. When the operator answers, the insertion of a plug into the answering jack operates relay *S*, which in turn energizes relay *SS*. ***SS*4** releases the answering lamp relay. When the operator throws her speaking key, relay *DR* operates due to the unbalanced currents in its two windings, and at ***DR*1** releases relay *LL*. *LL*2 and *LL*3 now disconnect ringing tone.

The recall facility described in the previous paragraph is obtained by the operation of the ringing key which energizes relay *RR*. Contacts ***RR*1** and ***RR*2** return ringing to the originating exchange for so long as the key is thrown.

Should the trunk circuit be re-seized at the selector level after the conclusion of a call but before the incoming operator has withdrawn her plug, relay *L* re-operates to the calling condition. ***L*1** operates *LL* as before, whilst ***LL*6** connects relay *LF* to the flicker earth supply. ***LF*1** now pulses at flicker earth speed and repeats the flicker signal to the cord circuit supervisory lamp over the sleeve conductor. When the operator throws the cord circuit speaking key, relay *DR* operates on the first release of *LF*. ***DR*1** releases *LL*, and *LL*6 disconnects the *LF* relay from the flicker earth supply.

The outgoing and incoming relay sets are designed to provide three alternative forms of signalling over the trunk circuit:

(*a*) *Generator signalling* as described above.

(*b*) *D.C. loop relay signalling.* With this scheme the calling condition is an earth connected to the *A*-line and a battery connected to the *B*-line. The recall signal is earth and battery returned on the *A*- and *B*-lines respectively from the manual exchange. At the outgoing termination the recall condition is received on a relay connected across the speaking pair.

(*c*) *D.C. earthed relay signalling.* With this scheme the calling condition is battery applied to both wires of the outgoing speaking pair. At the manual board termination the signal is received on an earthed relay connected to the centre-point of the line transformer. The recall signal is a battery returned on both wires of the trunk line which operates an earthed relay connected to the centre-point of the line transformer of the outgoing termination.

The same relays are used for the various forms of signalling, the alternative connexions being provided by suitable strapping arrangements. The basic signalling conditions for d.c. working are shown schematically in Fig. 727.

EXERCISES XXIII

1. Discuss some of the problems associated with the establishment of a comprehensive system of subscriber-to-subscriber dialling throughout Great Britain. What is meant by a "National numbering scheme," and what does the introduction of such a scheme involve?

2. Describe the general arrangements of the cordless switchboards installed at Melbourne trunk exchange. Enumerate the advantages of utilizing the "cordless" principle in the design of trunk switchboards.

3. Describe how demand calls from the local subscribers in the Melbourne area are routed to the trunk switchboard. What facilities are provided to ensure that the calls are dealt with approximately in the order in which they originate?

4. Describe, with the help of a simple trunking diagram, how a trunk operator at Melbourne can

set up a revertive call to a subscriber in the local network. In what ways does the Melbourne scheme for dealing with such traffic differ from the proposed British scheme?

5. Describe what happens if a Melbourne trunk operator keys up the routing digits for an outgoing trunk call at a time when all circuits in the first outgoing link are engaged. What happens if all lines in some subsequent link are engaged?

6. Explain, with the aid of suitable trunking diagrams, the proposed British system for distributing calls to the operators on the trunk switchboard. State precisely why, in the larger exchanges, it may be necessary to have several separate distribution systems. How is it proposed to keep the speed of answer substantially constant between the several distribution systems?

7. Describe how the traffic at a trunk exchange can be progressively concentrated on to a small number of positions during periods of light load. How is it proposed to cater for the subscribers' emergency (999) service?

8. Discuss the advantages of introducing a system of "sub-zone" centres to supplement the existing British network.

9 Under manual switching conditions a certain route between two zone centres has a total of thirty circuits. Twelve of these circuits are worked on a bothway basis, the remaining eighteen being divided into two groups each of nine unidirectional circuits. With the introduction of trunk mechanization this route will be accessible (from either end) from trunk selector levels. Suggest how the circuits should be worked under these new conditions. Sketch suitable grading arrangements for both ends of the route, assuming that the trunk selectors have an availability of 10.

10. Draw a trunking scheme suitable for use at a large zone centre exchange at which the following units are accommodated in one building:

A cordless trunk switchboard.

The main exchange of a multi-exchange area.

A trunk tandem exchange.

The repeater station.

It may be assumed that one-third of the total outgoing traffic from the trunk switchboard is connected over direct routes to nearby exchanges and that the remaining traffic from the trunk switchboard is approximately equally divided between the trunk system and the local network.

CHAPTER XXIV

PRIVATE AUTOMATIC BRANCH EXCHANGES

A SINGLE telephone instrument will often suffice to meet the communication requirements of residential subscribers, small shopkeepers, and perhaps business houses where the number of people who require telephone facilities is small. In somewhat larger organizations it may be desirable to make the exchange line available to several different persons by the provision of "extension" instruments conveniently located in the various offices, etc. The standard Plan Nos. described in Vol. I are designed for use in such circumstances. In still larger business organizations the volume of telephone traffic may justify the provision of a number of lines to the public exchange, and these lines must be accessible to a large number of telephone using staff. Moreover, as the size of the firm increases, it becomes more and more desirable to provide telephone facilities between the various departments in addition to the normal exchange line services. The switching of a number of exchange lines to any one of a large number of extension points, and the provision of communication facilities between these extension points, require the provision of some more or less complex switching arrangement at the subscriber's premises.

The switching equipment can be designed on a manual basis, i.e. the connexions can be set up manually by a telephonist provided by the subscriber, or, alternatively, automatic switching plant can be installed whereby some or all of the connexions can be completed on a dialling basis by the extension users. If the desired switching is effected by means of a telephonist at a manual type switchboard, the installation is known as a Private Manual Branch Exchange (P.M.B.X.). If, on the other hand, automatic switching plant is installed, the installation is known as a Private Automatic Branch Exchange (P.A.B.X.). A P.A.B.X. may, of course, have a manual switchboard associated with it for the distribution of incoming calls, and, perhaps, for obtaining access to the public exchange. In some cases, business houses install an automatic system purely for communication between the various departments and without access to the public telephone network. Such an installation is known as a P.A.X. (Private Automatic Exchange).

P.M.B.X.s may be of various types, depending upon the facilities required. For the smaller installations (e.g. up to, say, 12 lines), a cordless type switchboard is quite satisfactory. For larger installations double cord switchboards, or even multiple type switchboards, may be required (see Vol. I).

At the present time there are comparatively few P.A.B.X.s in service (in the British Isles). There are, nevertheless, very material advantages in the provision of automatic switching at the subscriber's premises, and it is probable that there will be very considerable growth in the number of P.A.B.X. installations within a few years. From the subscriber's point of view, a P.M.B.X. installation consisting of, say, 5 exchange lines and some 30 extensions, requires the full-time attention of a telephonist. The wages and indirect charges of providing this telephonist add appreciably to the total cost of his telephone service. Even in smaller installations where there is insufficient traffic to justify the provision of a full-time telephonist, the operating work is of such a nature that there are continual interruptions to any other work given to the telephonist.

The provision of automatic equipment at the subscriber's premises does, of course, materially increase the capital cost of the installation. Automatic equipment also requires more maintenance. The annual charges of the equipment at the subscriber's premises are, however, comparatively small when compared with the charges for the external line plant. It is usually possible to offer automatic switching facilities to the subscribers at rentals which are not greatly in excess of those which are necessary to provide P.M.B.X. service.

Generally speaking, the switching principles used in public automatic exchanges can be applied to the design of P.A.B.X. equipment. Certain of the facilities required at a public exchange are not necessary with P.B.X. equipment but, on the other hand, there are various other requirements not normally provided in a public exchange which are very desirable in a subscriber's installation. The design of the equipment must take into consideration the fact that it may have to be installed in accommodation which may not be ideally situated for such equipment. Maintenance of P.A.B.X. equipment also presents a somewhat different problem from the maintenance of large automatic exchanges. Each visit to the

equipment may involve a considerable amount of travelling time, and the absence of facilities for adjustment of the equipment on site may still further add to the cost of maintenance. Reliability, and a design which requires the minimum number of maintenance visits, are therefore very important.

Attended and Unattended Installations. P.A.B.X. installations can be broadly classified under the heading of "Unattended" and "Attended." On unattended installations there is no manual switchboard at the subscriber's premises. Calls between extensions are completed automatically on a dialling basis through the local automatic equipment. Similarly, extensions can obtain outward calls via the public exchange by the dialling of a special code which gives access to the exchange lines. The equipment can be designed so that incoming calls are automatically routed to one or more selected extensions, and these extensions can, if necessary, transfer the calls to other extensions by dialling the required local number.

Unattended P.A.B.X. installations may be reasonably satisfactory where the number of exchange lines is limited (say, one or two), but on larger installations a more efficient method of distributing incoming calls is desirable.

On attended installations a manual switchboard (or attendant's cabinet) is provided for receiving incoming calls to the subscriber. The attendant can then extend the call to any desired extension, either through the local automatic equipment or by means of plugs and cords. In some cases the subscriber may wish to have all outgoing calls from the extensions to the public exchange routed through the P.A.B.X. operator. In other cases the subscriber may wish to provide automatic access to the public exchange for local calls, but to filter all outgoing trunk calls through the P.A.B.X. operator. These, and a number of other facilities required at P.A.B.X.s, are considered in the following paragraphs.

Local Dialling. In the interests of uniformity it is clearly desirable that calls between the various extensions of a P.A.B.X. should be set up on a decimal dialling basis utilizing the standard automatic telephone dial. A single digit numbering scheme would suffice for very small installations and would give a maximum capacity of 9 extensions, the 10th digit being available for obtaining access either to the P.A.B.X. operator or to the public exchange. A 2-digit scheme would provide for, say, a maximum of 90 extensions, whereas a 3-digit numbering scheme would serve an installation of up to, say, 900 extensions. There are very few Private Branch Exchanges which cannot be served by a 2- or 3-digit scheme. Such exchanges are exceptional and must be specially designed on the same lines as a large public exchange unit.

Control of Local Connexions. The standard practice in all public automatic exchange systems is to provide for the calling party (who pays for the call) to control the setting up and release of any local connexion. This principle is not necessarily the best for local calls on a P.A.B.X. installation. Extension-to-extension calls at a P.A.B.X. are not metered, and in all ordinary circumstances it is reasonable to assume that, when one of the two parties replaces his receiver, the conversation is finished and the switching train can be released. This *first party release* feature tends to reduce the holding time of the automatic equipment, so that the maximum economies can be effected in the quantity of switching plant. The provision of first party release also eliminates the called-subscriber-held condition, which can occur in a public exchange and which requires the provision of special alarm equipment to prevent the holding of a called subscriber's line after he has replaced his receiver. Even if a P.A.B.X. equipment is designed to give the more usual calling party release, it is clearly impracticable (in the absence of continuous engineering attendance) to provide a called-subscriber-held (C.S.H.) alarm system.

Permanent-loop Lock-out. Except in very large P.A.B.X. installations the total quantity of common switching equipment is usually comparatively small. Under these conditions it is important to minimize the possibilities of this common equipment being irregularly held due to mis-operation by the extension user, with the consequent degradation in the grade of service. This same problem exists at small Unit Automatic Exchanges. The difficulty can be avoided by the provision of a circuit which will isolate the extension line from the common switching equipment should permanent-loop conditions exist on that line (either due to the extension lifting his receiver and failing to dial, or due to fault conditions). The lock-out facility requires a timing circuit in the 1st selector so that, at the end of a predetermined period, the selector is forcibly released and isolated in the line circuit. The provision of permanent-loop lock-out facilities avoids the necessity of a P.G. alarm system on the 1st selectors at the P.A.B.X. Moreover, if the P.A.B.X. equipment is designed to give calling party release, the lock-out facilities provided in the extension line circuits can also be used to free the called extension and the common switching equipment under C.S.H. conditions.

Direct Access to Public Exchange. The automatic equipment at a P.A.B.X. can be designed to

give automatic access to the public exchange by the dialling of a special code. This facility very materially reduces the load on the P.A.B.X. operator and is generally desirable. The digit "9" has been standardized for this purpose. If the public exchange serving the P.A.B.X. is also automatic, then an extension user dials "9" to reach a 1st selector at the public exchange and then follows this with the 4- or 5-digit number required to obtain access to the called subscriber's number. The provision of direct access facilities usually involves very little additional automatic switching equipment at the P.A.B.X. It is in fact possible to design the system so that, after a call has been set up to a free exchange line, the common switching equipment at the P.A.B.X. is released. Hence, direct access can be provided without any increase in the quantity of common switching equipment at the P.A.B.X.

Restricted Service. Some subscribers may require facilities whereby any extension on the P.A.B.X. can obtain direct access to the public exchange without passing through the P.A.B.X. operator. In other circumstances the subscriber may wish to restrict this facility to a limited number of selected extensions. These requirements may vary in the course of time at any particular installation, and hence it is desirable that any P.A.B.X. with direct access to the public exchange should provide for the restriction of service to any extension as required.

Ordinarily, all subscribers' lines (including those from P.A.B.X.s) have access to the automanual switchboard for obtaining trunk and toll calls. If direct access is provided for the extension users at a P.A.B.X., then these extensions are in a position to make trunk calls without the knowledge of the P.A.B.X. operator. Similarly, any extension can obtain unlimited access to the various miscellaneous services (e.g. Phonograms, Speaking Clock, etc.) and to exchanges within automatic metering range. In a number of cases the subscriber may wish to restrict these facilities to certain extensions, or he may insist that all originated trunk calls should pass through the P.A.B.X. operator, These variable facilities cannot be given if the exchange lines from the P.A.B.X. are terminated on ordinary subscribers' uniselectors which have access to the common pool of 1st selectors serving ordinary subscribers. One possible solution is to provide two groups of circuits between the public exchange and the P.A.B.X. One group could then be reserved for the use of the P.A.B.X. operator and would give full access for trunk calls. The second group of exchange lines would be used only by the extensions at the P.A.B.X. and would be terminated on a special group of subscribers' uniselectors, the outlets of which are connected to a special "barred trunk" group of 1st selectors. Except with very large P.A.B.X. installations this solution would reduce the average traffic carrying capacity per exchange line, whilst the segregation of the switches in the main exchange would also degrade the efficiency of the public exchange switching plant.

An alternative solution is to provide auxiliary equipment at the main exchange on all lines from P.A.B.X.s. The P.A.B.X. equipment could then be designed to give a special discriminating signal when a call is originated by an extension user, and receipt of this signal by the auxiliary equipment at the exchange could be made to bar access to the trunk exchange. By the provision of such discriminating signals, it would be possible to retain all the P.A.B.X. exchange lines as one common group and to avoid any segregation of the switching equipment at the exchange.

Through Clearing. It is nowadays the standard practice to provide through clearing facilities on P.M.B.X. installations. The circuits are arranged so that, on an outgoing call, the replacement of the handset at the extension instrument gives a clearing signal at the P.M.B.X. switchboard and also at the public exchange. On trunk and timed toll calls, the clearing signal from the subscriber is used to stop the automatic timing device on the trunk switchboard. If through clearing from a P.M.B.X. extension is not provided, then there is a danger of excessive trunk call charges due to delays in clearing by the P.M.B.X. operator.

For the same reasons, through clearing is also desirable at a P.A.B.X. installation. Through clearing is available in all cases where direct access from the extensions is provided. It is standard practice to provide Operator Hold of the main exchange switching train on all calls to the trunk switchboard (and also, incidentally, to certain other miscellaneous services). In some cases this holding condition cannot readily be extended over the subscribers' lines to hold the switching equipment at the P.A.B.X. It is therefore possible for an extension user at a P.A.B.X. to make a trunk call and, at the end of the call, to release the local switches at the P.A.B.X. The switching train at the main exchange is, however, held by the trunk operator until she withdraws her plug from the "0" level circuit. In the absence of a guarding condition back over the subscribers' lines, it is possible for a second extension to seize the exchange line after such a trunk call and before the switching equipment at the main exchange has been released by the trunk

operator. Under these conditions, the second calling extension would not receive dialling tone from the main exchange after the initial digit, and would have to replace his receiver and repeat the call.

If all outgoing trunk calls are routed through the P.A.B.X. operator, arrangements can be made so that, when an extension replaces his receiver, a clearing signal is given simultaneously at the P.A.B.X. switchboard and at the public exchange. In some respects it is preferable that the automatic equipment at the P.A.B.X. should be arranged to free the calling extension from the P.A.B.X. switchboard immediately the receiver is replaced at the termination of a call. On the other hand, the adoption of this principle makes it necessary to prevent a second calling extension from seizing the "0" level circuit to the P.A.B.X. switchboard before the previous call has been cleared by the P.A.B.X. operator. This can be achieved either by artificially engaging the "0" level circuit or by providing Follow-on Call facilities, i.e. by arranging the circuit so that the second seizure of the "0" level circuit will prevent access to the connexion established to the public exchange and at the same time give a calling signal to the P.A.B.X. operator.

To cater for the control of the timing device on reverted trunk calls, it is desirable to provide through clearing direct from the extension on calls incoming to the P.A.B.X. This facility can be readily provided, but it involves the introduction of Follow-on Call facilities on the "0" level circuit at the P.A.B.X. for the reasons already advanced. As an alternative, arrangements can be made on incoming calls so that the automatic equipment at the P.A.B.X. is not released when the called extension replaces his receiver, but is deferred until the P.A.B.X. operator clears down the connexion. So long as there is no co-ordination between the holding of a circuit at a P.A.B.X. and the holding of the selector train in the main exchange, there is always a danger that a P.A.B.X. line may become free at the P.A.B.X. end although the main exchange end is still held. The only real solution to the problem is the provision of a signal from the main exchange to indicate when the circuits there have released. This signal could be utilized at the P.A.B.X. to guard the exchange line from re-seizure until such time as the line is clear at the public exchange.

Operator Recall and Manual Transfer. The adoption of through signalling prevents an extension from recalling the P.A.B.X. operator by flashing his cradle-switch. Any such action would give a clearing signal to the exchange, with the consequent danger of breaking down the connexion. It is nevertheless often very desirable that an extension user should be able to recall the P.A.B.X. operator when, for example, it is desired to transfer a call to another extension. The facility, whereby an extension user can obtain the attention of the P.A.B.X. operator during the progress of a call, is known as *Operator Recall.* The usual method of providing Operator Recall facilities is to provide a special button on the extension instrument, the depression of which gives a distinctive signal to the telephonist at the P.B.X. With P.A.B.X. working this signal is transmitted through the automatic equipment at the subscriber's premises, and can be used to provide a flicker signal on the appropriate connecting link of the P.A.B.X. switchboard. It is possible to provide Operator Recall facilities without the use of a separate press button at the extension instrument. One method is to dial "1" after the establishment of the call to set up the Operator Recall conditions through the automatic selectors, but this method is sometimes rather difficult to apply, especially on outgoing calls

When the Operator Recall facility is provided, it is clearly desirable to provide facilities at the P.A.B.X. manual switchboard so that the operator can transfer a call from one extension to another. This facility is sometimes known as *Manual Transfer.*

Call-back and Auto Transfer. Points may arise in the course of a conversation which make it desirable for an extension user to communicate with some other party in the organization. For example, an incoming call may be routed to the Sales Office, but the nature of the enquiry may make it necessary for the Sales Office to speak to the Despatch Department of the firm. Ordinarily, this requirement would necessitate a separate extension instrument which could be used for such enquiry calls whilst the first instrument is held on the exchange line call. This duplication of instruments is expensive and generally undesirable. Where the extensions are served by a P.A.B.X., it is possible to provide facilities whereby an extension can suspend an exchange line call and make a local call on the same extension instrument. At the end of the local call, he can return to the original exchange line connexion. The *call-back* facility can be provided by a press button on the extension instrument which, when operated, splits the exchange line circuit, leaving the main exchange line held but connecting the extension to a local selector in the P.A.B.X. equipment. The extension can then dial the

required local number, and at the end of this call can return to the original connexion by pressing the extension instrument button a second time.

A useful development of the call-back feature is the provision of facilities whereby an exchange call can be transferred automatically to some other extension without the aid of the P.A.B.X. operator. The extension can communicate with the party to which the call is to be transferred by the operation of the call-back key as described above. When the required extension replies, the original extension can transfer the awaiting exchange call by merely replacing his handset.

Calls to P.A.B.X. Operator. The standard code for obtaining access to the automanual board operator in a public exchange system is the dialling of the digit "0." To maintain uniformity the digit "0" has been standardized for obtaining access from the extensions of a P.A.B.X. to the operator at the P.A.B.X. switchboard.

On some cord-type P.A.B.X. switchboards there is a complete outgoing multiple jackfield to give access to the extensions for the completion of incoming calls. In such cases it is possible to provide equipment in the 1st selector circuit of the local switching train which, when the digit "0" is dialled, will light a lamp associated with the extension multiple jack. This facility is sometimes known as "0" *level reversion to manual board.* By its use an appreciable volume of traffic is removed from the local automatic switching train, which permits of a material reduction in the total quantity of switching equipment. An additional relay may be required in the extension line circuit to provide this facility, and arrangements are required in the 1st selector for a signal to be returned to the line circuit when the wipers are stepped to level 0. In addition, a calling lamp is required per extension.

Secrecy, Preference, and Trunk Offering Facilities. Some business subscribers prefer that the operator at the P.A.B.X. switchboard should be debarred from entering an established connexion—either local or via the main exchange. The facility can readily be given on P.A.B.X. equipment, and there are no particular disabilities when it is applied to extension—extension calls. The adoption of secrecy measures on calls via the exchange line does, however, tend to increase the difficulties of monitoring and supervisory work.

In most cases it is desirable to give the P.A.B.X. operator facilities to enter an established connexion in order to offer a trunk call. If trunk offering facilities are required on an installation designed to give secrecy, then it is necessary to arrange for the equipment to give a warning tone to the parties concerned whenever the operator makes use of the trunk offering access to an established connexion.

P.A.B.X. subscribers sometimes require facilities whereby certain privileged parties may enter existing connexions in spite of the engaged test. This *preference* facility can be provided by the inclusion of additional equipment in the final selector circuit which will respond only to a signal from the preference extension instruments. A press button is usually associated with the selected extension instruments, and the operation of this button applies earth to the calling loop which upsets the balance of current in the windings of a relay in the final selector circuit. Contacts of this relay are in turn utilized to effect switching, irrespective of the engaging condition on the *P*-wire. In the absence of this facility, the requirements can often be met by the use of the trunk offering circuits from the P.A.B.X. switchboard.

Miscellaneous Facilities. There are many other facilities of lesser importance which can be provided for a P.A.B.X. subscriber. Certain subscribers may, for example, require facilities whereby a number of selected extensions can all be placed into communication with each other for conference purposes. Generally speaking, it is preferable to provide conference facilities by means of auxiliary equipment rather than to complicate the design of the P.A.B.X. switching circuits. One method is to provide a special box alongside the P.A.B.X. switchboard which contains keys for each party having conference facilities. The operator can then ring any or all of the parties and ask them to join the conference by throwing the appropriate switching keys.

Other subscribers may wish to incorporate, in a P.A.B.X. system, facilities whereby certain administrative heads can obtain immediate access to selected extensions without the necessity of dialling. Usually such facilities are provided by push buttons associated with the extension instrument which give direct connexion with the required extension. This form of immediate access is of value where a busy extension frequently has occasion to call a limited number of other extensions.

Sometimes there is a demand for a system of signalling (either visually or orally) so that a party, whose whereabouts are unknown, can be called to the telephone. Usually a system of code numbers is designed, and suitably displayed at various parts of the office and works so that any required party can be called to the telephone.

Types of P.A.B.X. In the past, P.A.B.X. equipment was not included in the standard facilities available to the subscriber. If a subscriber particularly desired such facilities, he made separate arrangements with the manufacturer who generally undertook the work of installation. Although the designs produced by various manufacturers were approved by the Post Office before being brought into service, no attempt was made to effect any real degree of standardization. There are therefore many types of P.A.B.X. equipment in service to-day which vary widely, both in the design of the circuits and in the facilities provided. P.A.B.X. schemes. For purposes of illustration, one example of each of the above three main types is given in the following paragraphs.

P.A.B.X. No. 4. Fig. 728 shows the main trunking arrangements of a P.A.B.X. installation utilizing uniselector mechanisms. This particular unit was designed many years ago, but there is a fair number of installations using this equipment still in service. The basic unit has a capacity for 40 extension lines and 6 connecting circuits. By using two such units it is possible to serve an installation with up to 70 extensions, and this number can be still further increased (exception-

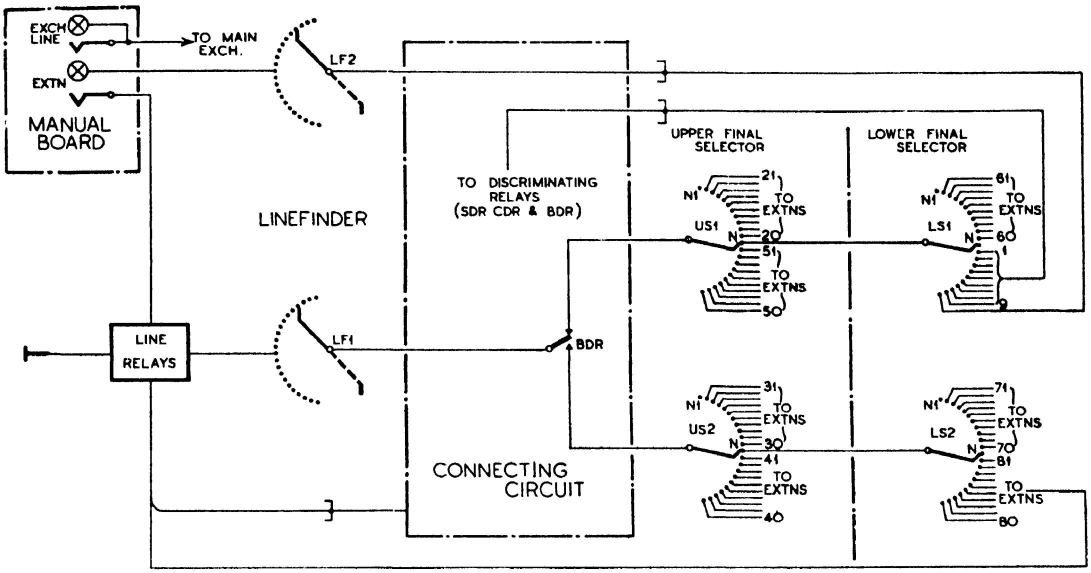


Fig. 728. General Trunking Arrangements of P.A.B.X. No. 4

In general this equipment can be broadly classified under:

(*a*) Uniselector switching schemes in which the required extension line is selected by means of uniselector mechanisms.

(*b*) Strowger systems using 2-motion selectors as the main switching medium.

(*c*) Relay switching systems.

The uniselector type of installation is particularly suitable for small organizations where the number of extensions is limited to, say, 25 or perhaps 40. The systems utilizing 2-motion selectors have in general been used on the larger installations where a capacity of 1000 or more extensions is required. The relay system of switching is particularly attractive for P.A.B.X. work in view of the small amount of maintenance attention which is required with this type of equipment. It is not possible in this volume to give more than a broad outline of typical

ally) to 140 lines by the addition of a special group selector unit. The units are completely enclosed and are designed to operate on a 36 V power plant.

Each connecting circuit comprises a group of relays (flat type), a 44-point 6-level linefinder, and 2 final selectors of the uniselector type. The bank of each final selector is divided into two distinct portions, which can be selected by means of a wiper switching relay to give access to two different groups of lines.

When a subscriber lifts his receiver, the operation of the line relay transmits a start signal to all free connecting circuits. All the linefinders associated with these free connecting circuits now hunt for the calling line, and when one linefinder reaches the marked contact, the hunting circuit of the remaining linefinders is disconnected.

A 2-digit scheme is adopted for the extension numbers. The first digit is utilized as a discriminating signal to determine the appropriate final

selector, the appropriate group of wipers on this selector, and the correct half of the selector bank. Ordinarily, the wipers of both final selectors stand at the central normal position (N in Fig. 728). The first impulse train causes the wipers of the "lower" final selector to step in response to the digit dialled. Contacts 12 to 22 of the No. 1 arc of this selector are wired (via a common multiple) to discriminating relays in the connecting circuit. There are three such discriminating relays known as:

Selector discriminating relay .	*SDR*
Brush discriminating relay . .	*BDR*
Contact discriminating relay .	*CDR*

The relays are operated from the position of the *LS1* wiper as follows:

Digit	Relays Operated		
1	N.U. Tone		
2	*SDR*		
3	*SDR*	*BDR*	
4	*SDR*	*BDR*	*CDR*
5	*SDR*	—	*CDR*
6	—		—
7	—	*BDR*	—
8	—	*BDR*	*CDR*
9	N.U. Tone		

Thus, if the calling extension dials the digit "2," relay *SDR* in the connecting circuit is operated via contact 13 of the *LS*1 bank. Contacts of this relay switch the circuit so that the first arc (*US*1) of the upper final selector is used to complete the call. The final selectors automatically move to the second normal position ($N1$) during the inter-digit pause so that the second impulse train will select a subscriber's line in the first group of contacts on the *US*1 bank, i.e. a line in the 21–20 group.

If the digit "3" is dialled, discriminating relay *BDR* is operated in addition to *SDR*, so that the call is switched to the *US*2 arc and thence to a line in the 31–30 group. Similarly, if digit "4" is dialled, relay *CDR* is operated in addition to the *SDR* and *BDR* relays. *CDR* arranges the circuit so that the wipers move round to position N (instead of $N1$) during the interdigit pause. Other digits are dealt with in a similar way, a particular group of 10 contacts being chosen in each case by predetermination of:

(*a*) the appropriate selector (*US* or *LS*),

(*b*) the first or second group of levels on the chosen selector,

(*c*) the first or second group of 10 contacts in the selected group of levels.

Calls to the main exchange are obtained by dialling "0" in order to obtain access to the P.A.B.X. manual board. When this digit is dialled, the appropriate calling lamp on the manual board is lighted via the *LS*1 wiper and bank and an auxiliary arc (*LF*2) of the linefinder. Each extension line appears on the manual board, and the operator completes the call by means of plugs and cords in the usual way.

The connecting circuit incorporates a sequence switch which is designed to rearrange the circuit conditions at each stage of switching. For example, when the sequence switch is in position 2, the calling extension is receiving dial tone. When the switch moves to position 4, the circuit is ready for receiving the units digit. The circuit arrangements provide for first party release and for forcible release from the common connecting circuits after a 1-minute delay under P.G. conditions. When an extension line is forcibly released in this manner, the calling condition is diverted to the P.A.B.X. manual board.

Large Capacity Strowger P.A.B.X. Fig. 729 shows the trunking scheme of a typical P.A.B.X. of the larger type. In this particular case there is a capacity for 600 subscribers' lines utilizing a 3-digit numbering scheme. The trunking arrangements follow the same general lines as those of a Strowger type public exchange with 200-point 2-motion linefinders, group selectors, and final selectors.

When an extension user lifts his receiver, a signal is transmitted from the line circuit to the start circuit and thence to a free control relay set. This control relay set preselects a free linefinder which is caused to hunt for the calling line immediately on receipt of the start signal. When the line is extended to the group selectors, the extension user receives dial tone and proceeds to set up the number in the usual way, i.e. the first digit is accepted by the group selector, and the two final digits are accepted by the final selector.

The exchange lines are accessible either from the P.A.B.X. manual board or via level 9 of the group selectors. An additional wire is provided between the linefinder and the first group selector so that access to the group of exchange lines can be barred to callers on any predetermined linefinder levels. By this arrangement it is possible to group those extensions who are barred direct access to the public exchange on one or more linefinder levels and to arrange for a discriminating signal to prevent calls being established over level 9.

Access to the manual board is obtained by dialling the digit "0." In order to economize in the quantity of common switching plant, the

circuits are arranged so that group selectors are not engaged on calls to the P.A.B.X. manual board. Each extension line circuit is terminated on a jack and calling lamp on the manual board. If the extension dials "0," the digit is received in the group selector in the normal manner, but the connexions of the vertical marking bank are so arranged that the backward holding earth on the *P*-wire is disconnected when the wipers are moved to the 10th level. On receipt of this break in the backward holding condition, the subscriber's line circuit lights the extension lamp on the manual board. The call is then answered by the manual board operator via the extension jack. The same basic signalling circuits also provide for the forcible release of the common equipment should any selector be seized but not stepped within a specified period. The lighting of the calling lamp under forced release conditions draws the attention of the operator to the P.G. condition on the extension line.

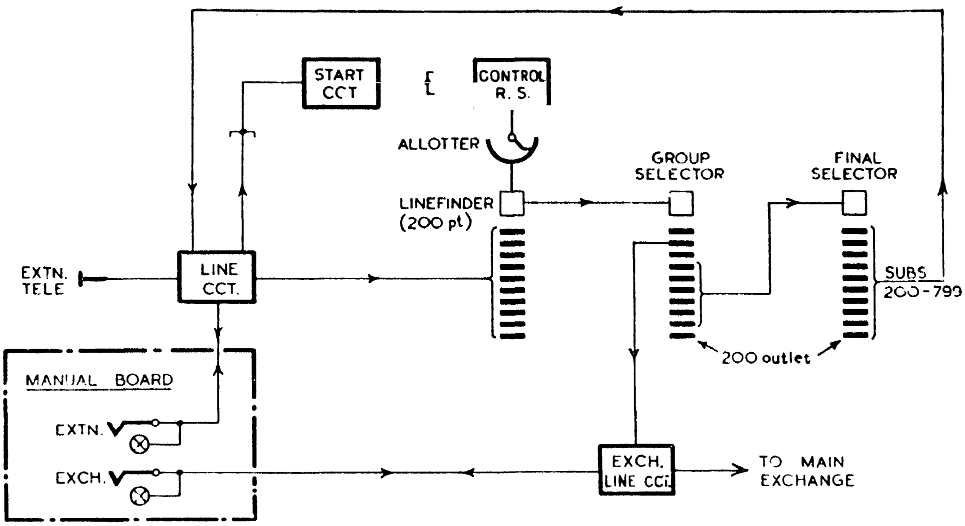


FIG. 729. TYPICAL TRUNKING SCHEME OF P.A.B.X. WITH 2-MOTION SELECTORS

The P.A.B.X. also includes preference facilities so that selected extensions can obtain access to any other extension, irrespective of whether or not that extension is already engaged. The "preference" extensions are concentrated on one particular level of the linefinder bank and, when a call is originated from this level, normal post springs of the linefinder operate to apply a low resistance battery potential to the *P*-wire. This discriminating signal is passed forward to the final selector where it is used to prepare a circuit for priority access. If one of the preference extensions sets up a call and encounters the engaged condition, he can interrupt the existing conversation and speak to the required extension by operating a press button on the telephone instrument. This press button is arranged to apply an earth to the calling loop which, by unbalancing the current in the two line conductors, operates a differential relay in the final selector. The contacts of this relay switch the caller through to the required number irrespective of the engaged condition. The final selector responds to the earthed line signal only if the call emanates from a line which provides the necessary discriminating signal over the *P*-wire.

Relay Type P.A.B.X.s. The main principles of the relay system of automatic switching have already been considered in Chapter XXI. One of the chief criticisms of the system for public exchange work is the comparative complexity of the circuit arrangements as the number of lines is increased. The system does nevertheless possess a number of advantages for small automatic switching units, such as Private Automatic Branch Exchanges, where the absence of mechanical selectors minimizes the amount of maintenance attention necessary. The system is also very silent in operation, and an automatic switching unit can be located in offices where Strowger equipment would be unsuitable. The most common type of relay P.A.B.X. is the 50-line unit. This unit comprises:

(*a*) 10 subscribers' units, each of which accommodates 5 subscribers' lines. The main purpose

of the subscribers' unit is to seize a free link when a call is originated, and to connect the chosen link to a free relay group known as an "A and B feed."

(*b*) The A and B feed contains the transmission bridge, the various relays for ringing the called line, etc., and, when taken into use, seizes a free recorder.

(*c*) The recorder receives, counts, and stores the dialled impulses and, when the required line has been determined, it passes the signals to a further group of relays known as the marker.

(*d*) The marker now applies electrical conditions to cause the switching of the required line to the A and B feed. This switching is effected by

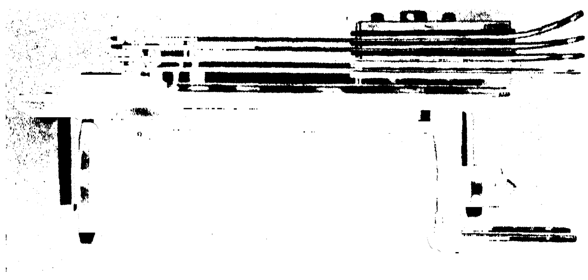


FIG. 730. DESIGN OF RELAY USED IN "RELAY SYSTEM"

means of a trunk connecting group in conjunction with the "in-trunk connecting" relays.

A 50-line system usually has a capacity for six A and B feeds, and provision is made for two recorders. The normal voltage for small units is 24 V.

Type of Relay. All switching operations are carried out by relays of the type illustrated in Fig. 730. A distinguishing feature of the relays is the use of a common yoke to serve a number of relays. The armature of each relay is mounted on a simple knife-edge, displacement being prevented by the provision of a friction-tight nut working on a screwed rod which passes through a hole in the armature. Complete closure of the magnetic circuit is prevented by the use of an L-shaped residual strip of thin brass, which is fastened to the under side of the yoke. The spring sets are self-contained units with a single screw fixing to the yoke. The springs are of phosphor-bronze and are designed for working at somewhat higher contact pressures than is normal with relays of the P.O. standard type. There are usually two spring piles per relay, but the spring capacity can be increased to as many as six separate spring piles by the use of a suitably widened armature.

Subscriber's Unit. The detailed circuit arrangements of a subscriber's unit are given in Fig. 731. For simplicity the diagram has been limited to show two subscribers' lines, two links, two out-trunks and two in-trunks.

When the calling subscriber lifts his receiver, relay *LE* operates to the loop. ***LE*2** provides a circuit for the out-trunk test relay (*OTT*) which, in turn, completes the circuit of the out-trunk test wires via the link-marking relays (*LM*). The free condition of an out-trunk is indicated by a battery on the test wire, whilst a disconnexion of the test wire indicates the busy condition. Any link can be used for either incoming or outgoing calls (i.e. it may connect a line either to an out-trunk or to an in-trunk), and consequently the test wires of the out-trunks are taken through a contact of the in-trunk connecting relay (*ITC*).

The only *LM* relays which can operate are those which receive battery on the test wire. If relay *LM* associated with the first free out-trunk operates, ***LM*4** immediately disconnects the remaining *LM* relays. Relay *OTC* operates in series with *LM* and connects the link to the out-trunk. Contact ***LM*5** operates the link-connecting relay (*LC*), and the calling line is now extended to the link and, via the out-trunk, to the selected A and B feed. The seizure of the A and B feed disconnects the battery on the test wire, and relay *LM* releases. Relay *LC*, however, remains held from the earth on the hold (*H*) wire via ***OTC*1** to the battery at relay *F*. Relays *CO* and *F* operate over this circuit. Contacts ***CO*1** and ***CO*3** release relay *LE*, whilst ***CO*2** connects an engaged test battery to the bush of the extension jack of the P.A.B.X. manual board. The units-marking wire is opened at ***F*2** to busy the calling line against intrusion. *LE*2 now releases relay *OTT*. The circuit is held during the conversational period by earth on the hold wire from the A and B feed, and at the end of the call (when the calling subscriber replaces his receiver) this earth is withdrawn and relays *F*, *CO*, *LC*, and *OTC* are released.

On an incoming call, the switching is controlled by conditions sent out from the marker. The placing of an earth on the fives-marking wire operates the in-trunk test relay (*ITT*) which extends all five units-marking wires to the five *LC* relays. Contact ***ITT*6** disconnects the *OTT* relay circuit to prevent the link being seized by any calling subscriber who may happen to lift his receiver at this stage. The test wires of the in-trunks are extended to the *ITC* and *LM*

relays. The in-trunk to be used for the call has battery on its test wire from the recorder via the A and B feed. This in-trunk is chosen in the same manner as described for an out-trunk, relay *LM* associated with the first free link operating from battery at the *ITT* contact to the earth at *LM*4.

call are indicated by a disconnexion of the test wire at ***OTC*2**. If the in-trunk is busy, the test wire is disconnected in the trunk connecting group.

The release of an incoming call is effected by the removal of earth on the hold wire which releases relays *F*, *CO*, *LC*, and *ITC*.

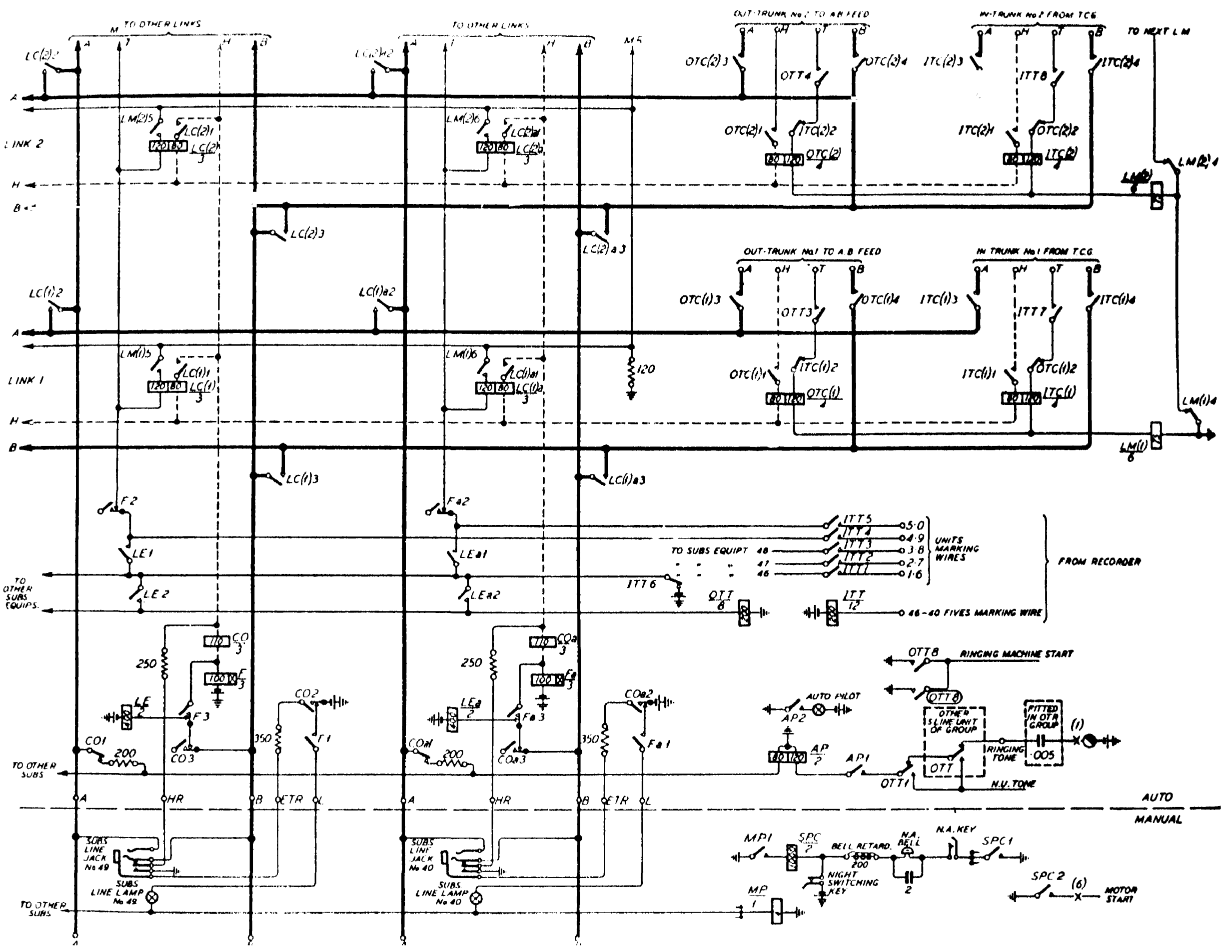


FIG. 731. CIRCUIT ARRANGEMENTS OF SUBSCRIBER'S UNIT

Relay *ITC* also operates and extends the in-trunk to the link. The marker now connects battery to the units-marking wire to operate relay *LC*. Relay *ITT* is next released, and the connexion is held by the earth on the hold wire in the A and B feed. Relays *F* and *CO* operate over this circuit and function as described above.

If the called line is engaged the units-marking wire is disconnected at ***F*2**, and this causes the return of busy tone from the A and B feed. Similarly, links which are busy on an outgoing

A and B Feed. Fig. 732 shows the circuit arrangements of the A and B feed, together with the recorder connecting relays. When the A and B feed is disengaged, battery from the thermostat relay is applied to the incoming *T*-wire. When the circuit is seized from a subscriber's unit, relay *BBM* operates, and ***BBM*2** connects earth on the hold wire to the unit. ***BBM*3** closes the circuit of the thermostat relay, whilst ***BBM*1** prepares a holding circuit for the 45 Ω coil of relay *BBM* and an operating circuit for the recorder prepare

relay (*RP*). The calling loop operates relay *A*, and **A1** in turn completes a circuit for the guard relay *G*. **A2** opens the circuit of the impulse wire. The **G1** contact completes the holding circuit of relay *BBM* and operates *RP*. At the same time **G2** disconnects the initial operating circuit of *BBM*, whilst **G3** takes over the function of contact ***BBM*2**.

The operation of relay *RP* completes the test wire circuits to the recorders via *RC*. The *RC* relay associated with the first free recorder operates, and disconnects any other *RC* relays associated with free recorders. ***RP*3** returns dialling tone to the caller, whilst ***RP*4** removes the short circuit from the 200 Ω winding of relay *FI*. ***RP*5** disconnects the impulse wire to the recorder and, at the same time, prepares a circuit for the reception of the first impulse by relay *FI*. At this stage the recorder is not busied and can be taken into use by another A and B feed. Should dialling commence via this second feed, relay *RC* will be released (due to the disconnexion of the test wire in the recorder), and another *RC* relay will operate to seize an alternative recorder.

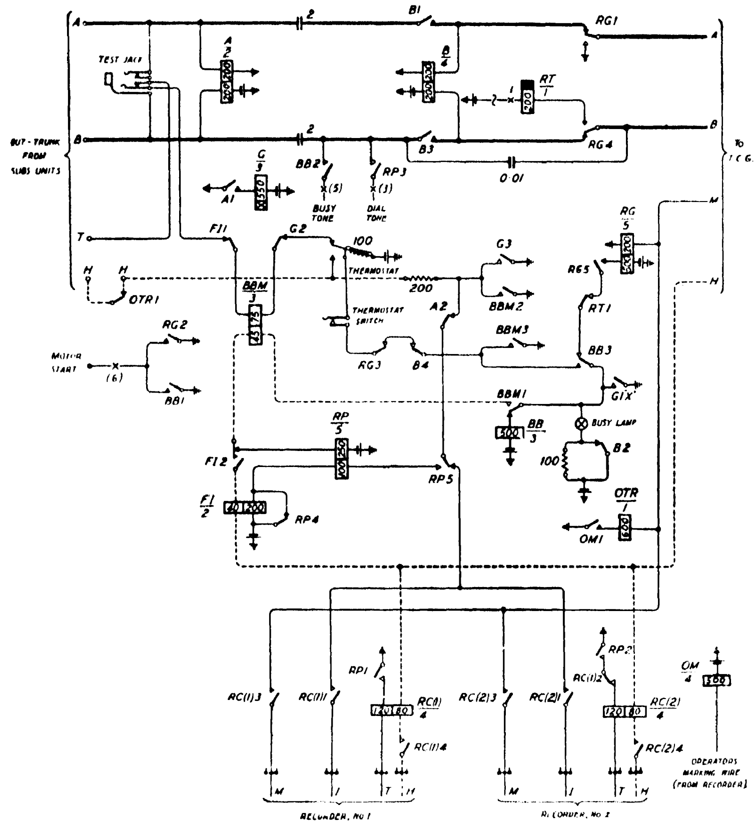


FIG. 732. CIRCUIT OF A AND B FEED WITH RECORDER CONNECTOR

When the calling subscriber dials, the first release of *A*2 operates relay *FI*. ***FI*2** retains *FI* and breaks the holding circuit of relay *RP*, which is now dependent upon the circuit via the *A*2 contact. When relay *A* re-operates at the end of the first impulse, *RP* releases. Relays *RC*, *FI*, and *BBM* are now held from the **G1** earth to battery on the hold wire in the recorder. *RP*5 extends the impulse wire (via ***RC*1**) to the recorder. The second and succeeding impulses are transmitted to the recorder in the form of earth pulses via contact *A*2. It will be seen that the first impulse of the first train of impulses is not passed to the recorder, but allowance is made for this in the counting arrangements of the latter. The whole purpose of relay *FI* is to prevent the mutilation of a call due to a false initial impulse.

After receipt of the impulse train, the recorder applies the appropriate conditions to the marking wires and, when switching is completed, the hold wire to the A and B feed is disconnected. The ringing relay (*RG*) now operates from the battery on the marking wire and locks to ***RG*5**. ***RG*1** and ***RG*4** extend ringing current via the ring-trip relay (*RT*) to the called line, whilst, at the same time, ringing tone is returned to the caller via the 0·01 μF capacitor.

When the called subscriber answers, *RT* operates and at ***RT*1** releases relay *RG*. The called line is now extended to relay *B*, which operates to the loop. **B1** and **B3** complete the switching of the speech conductors, whilst **B2** inserts a 100 Ω resistor in series with the busy lamp of the A and B feed, so that the lamp glows at half brilliance. **B4** takes over the function of ***RG*3**. Relays *FI* and *BBM* are now held to the hold wire of the out-trunk.

If the called line is engaged, the condition is indicated by a disconnexion of the hold wire of the out-trunk. When the recorder disconnects the hold wire circuit, there is now no alternative holding condition, and relays *FI* and *BBM* release. The busy relay (*BB*) now operates from the earth at **G1**, whilst **BB2** connects busy tone to the caller.

When the calling subscriber replaces his receiver, *A* releases and, after a delay period, *G* releases. *G*1 removes the earth from the hold wire of the out-trunk to release relays *FI* and *BBM*. *BBM*2

now disconnects the earth on the hold wire to the subscriber's unit.

Under called-subscriber-held conditions, relay *B* releases, but the hold wire circuits are maintained. *B*4 now closes the circuit of the thermostat relay and, after a period of approximately 1 min, the changeover of the thermostat contacts applies battery to the hold wire to short-circuit the relays in the subscriber's unit. This produces forced release conditions, and the removal of the loop allows relay *A* and the whole of the A and B feed to release. Forced release conditions are also applied if a caller encounters busy tone and does not replace his receiver within the 1 min delay period.

Under permanent loop conditions, the circuit of the thermostat relay is closed immediately on seizure of the A and B feed. As before, the forced release condition is applied at the end of 1 min to disconnect relays *F*, *CO*, *LC*, and *OTC* in the subscriber's unit. Relay *F* is slugged and, before it has time to release, *CO* restores. *F* is now connected to the calling line at *CO*3 (Fig. 731) and remains held for so long as the calling loop persists. ***F*1** lights the calling lamp on the manual switchboard.

The subscriber dials "0" for calls to the P.A.B.X. manual board. Under these conditions the recorder applies a marking condition to the operator marking wire. This operates the *OM* relay (Fig. 732), and ***OM*1** now allows relay *OTR* to operate when the recorder connects earth to the marking wire. ***OTR*1** disconnects the hold wire to the subscriber's unit, and the call appears at the manual board due to the retention of relay *F* (Fig. 731) as already described. By this arrangement all the automatic apparatus is released on a manual board call.

In some of the later equipments, the resistance of the *A* and *B* relays has been decreased to 100 Ω to increase the permissible resistance of the extension lines. The *B* relay make contacts in the speaking pair have also been removed in the later circuits, and relay *G* is shunted by a resistor to improve its characteristics.

Recorder and Marker. The connexions of a 2-digit recorder and its associated marker are given in Fig. 733. The recorder is seized from an A and B feed as described above over the test wire. Relay *P* operates on seizure, and ***P*1** prepares a circuit for the recorder busy relay (*BY*). ***P*2** connects the battery common to the recording relays. The busy lamp now glows at half brilliance, and the "prepared" lamp glows fully. The digit control relay (*RG*) now operates to disconnect the tens storing relays (*TN*) at ***RG*1**. In Fig. 733 the figures in brackets after the *TN*, *U*, and *I* relays refer to the number of impulses which cause the relay to operate. The *U* and *I* relays are counting relays, whilst the *TN* relays are provided for the storage of the tens digits. (No special storage relays are required for the units digits since, on the last digit, marking conditions can be sent out direct from the impulse counting relays.)

The operation of ***P*2** completes a circuit for relay *I*, and ***I*(1·6)2** disconnects relay *U*(1·6). The remaining *U* relays operate from the battery via ***P*2** to the earth at the *I*2 contacts of the remaining four *I* relays. The *I*(1·6) relay now locks through ***U*(2·7)2**, and the impulse hold relay (*IH*) is short-circuited by the earth at *BY*3. The recorder is now prepared for dialling.

When the first impulse is received by relay *FI* in the A and B feed, the hold wire is earthed by ***FI*2**. Relay *BY* operates to the battery via ***P*1**, and ***BY*1** disconnects the test wire to busy the recorder. The busy lamp now glows at full brilliance. ***BY*3** removes the short circuit from relay *IH*, which operates in series with relay *I*(1·6). ***IH*2** connects relay *RG* to the impulse wire, and this relay is now dependent upon the earth impulses over the impulse wire.

On receipt of the first earth on the impulse wire, relay *I*(2·7) operates, and the fourth contact of this relay locks relay *I*(2·7) in series with *IH*. ***I*(2·7)2** disconnects the initial operate circuit of relay *U*(2·7) and this relay releases when the earth is removed from the impulse wire. *U*(2·7)2 opens the circuit of relay *I*(1·6), and the latter releases. *I*(1·6)2 now completes a circuit for the operation of relay *U*(1·6). In a similar manner the reception of the next earth on the impulse wire operates relay *I*(3·8) and, at the end of the impulse, relay *U*(3·8) and *I*(2·7) are released, whilst relay *U*(2·7) operates. If the impulse train consists of more than five impulses, the sixth impulse operates relay *I*(1·6) and, at the end of this impulse, relay *U*(1·6) releases to disconnect relay *I*(5·0) which, in turn, operates relay *U*(5·0). The tens changeover relay (*TN*6*C*) now operates, and ***TN*6*C*1** changes over the fives main marking wire to the marker.

The reception of further impulses operates and releases the *U* and *I* relays in the manner already described, and at the completion of the first impulse train *RG* releases. *RG*1 operates the appropriate *TN* relay (depending upon which *I* relay is operated at the end of the train). ***TN*2** releases *IH*, whilst *TNH* operates in series with the holding coil of *TN*. The release of relay *I* and the operation of the corresponding *U* relay now prepares the recorder for the receipt of the next train of impulses,

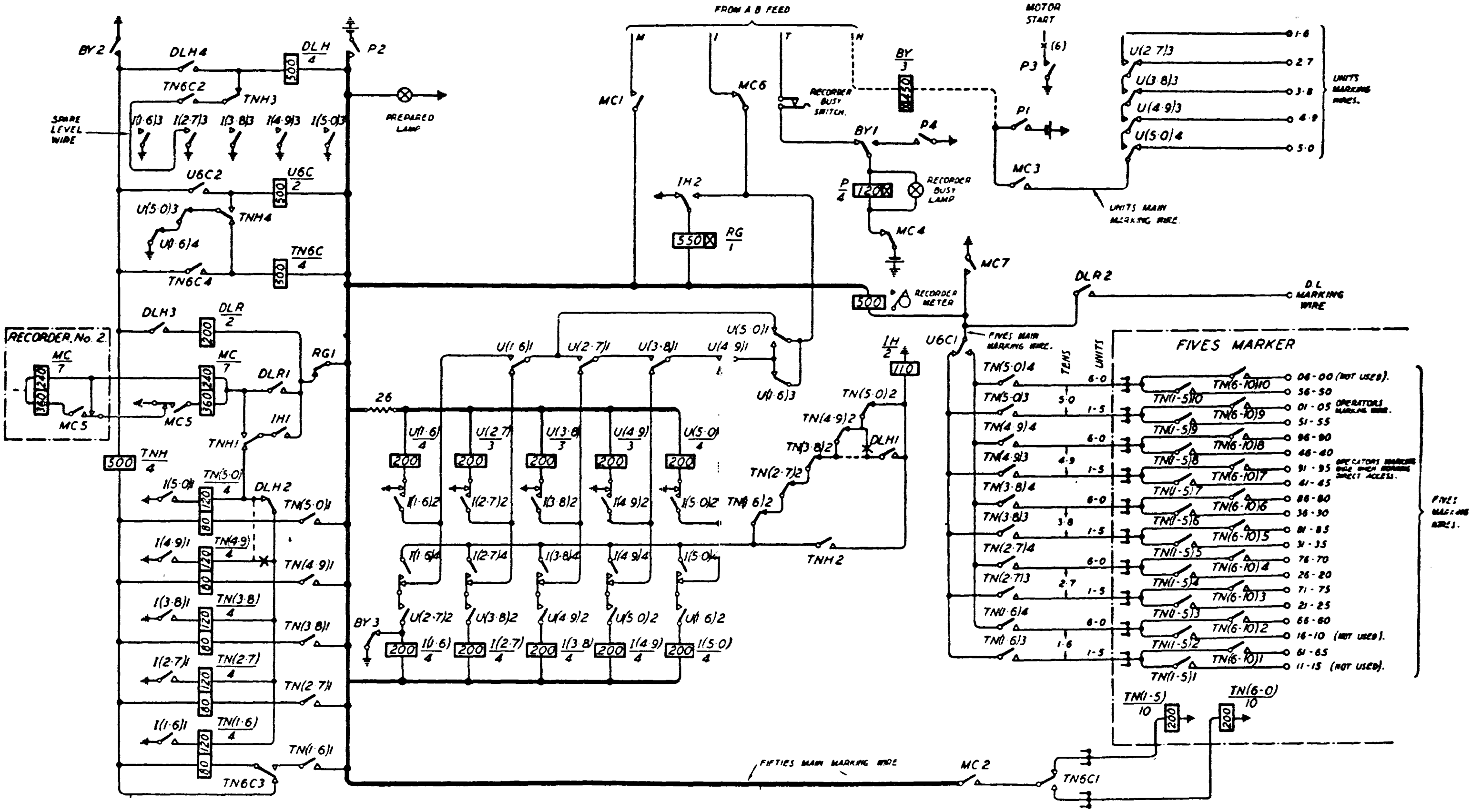


FIG. 733. TWO-DIGIT RECORDER AND MARKER

the first train being stored by the holding of a particular *TN* relay. The ***TN*3** and ***TN*4** contacts (in conjunction with ***TN*6*C*1**) have now prepared the circuits for two fives-marking wires, but the particular one of these two marking wires to be used awaits the receipt of the final impulse train.

The last train of impulses is counted on the *I* and *U* relays as already described, with the exception that the cycle commences with the operation of the *I*(1·6) relay. If the digit dialled is greater than 5, relay *U*6*C* operates when the sixth impulse is received in a manner similar to that already described for relay *TN*6*C*. Contact ***U*6*C*1** changes over the fives main marking wire. At the completion of the impulse train, *RG* releases and *RG*1 operates *MC*. ***MC*2** operates either relay *TN*(1·5) or *TN*(6·0) in the marker, depending upon whether relay *TN*6*C* is normal or operated. ***MC*4** disconnects relay *P* and extinguishes the busy lamp. ***MC*7** connects earth via *U*6*C*1, and the contacts of the *TN* relay, to a particular fives-marking wire, to operate relay *ITT* in the corresponding subscriber's unit. At the same time ***MC*3** connects battery from ***P*1** to the units main marking wire and to the individual units-marking wire, depending upon the setting of the *U* relays at the end of the impulse train. After a delay period, relay *P* releases, and all relays in the recorder restore to normal.

On calls to the switchboard it is necessary for the recorder to mark out on receipt of a single digit. On receipt of an initial digit "0," relay *DLH* operates at the commencement of the 7th impulse. At the end of the complete impulse train, *RG* releases and operates relay *TN*(5·0). The locking circuit for this relay also energizes relay *TNH*. Relay *MC* operates, and ***MC*7** connects earth to the operator marking wire and thence to relay *OM* in the A and B feed.

The *DLH* and *DLR* relays have been omitted from the latest recorder circuit, and the circuit is so arranged that, if the chain of break contacts on the *TN* relays is broken at the end of the first impulse train, the recorder will accept another train. Conversely, if this chain is unbroken, the recorder will mark out immediately.

Trunk Connecting Group. Fig. 734 shows a portion of the trunk connecting group. When the recorder marks out, battery is applied to the marking wire from the A and B feed. The out-trunk marking relay (*OTM*) operates to this battery and extends the marking wire to the test wires of the in-trunks via the 120 Ω coil of the out-trunk-to-in-trunk connecting relay *OT*/*IT*. The test wires of those in-trunks which are engaged are disconnected at ***ITB*1**. The first free in-trunk is chosen by the operation of an *LM* relay in the subscriber's unit, and the corresponding *OT*/*IT* relay operates and locks over its 80 Ω coil and the hold wire. The in-trunk busy relay will not operate with the current flowing in its 7 Ω coil and is differentially wound so that it does not

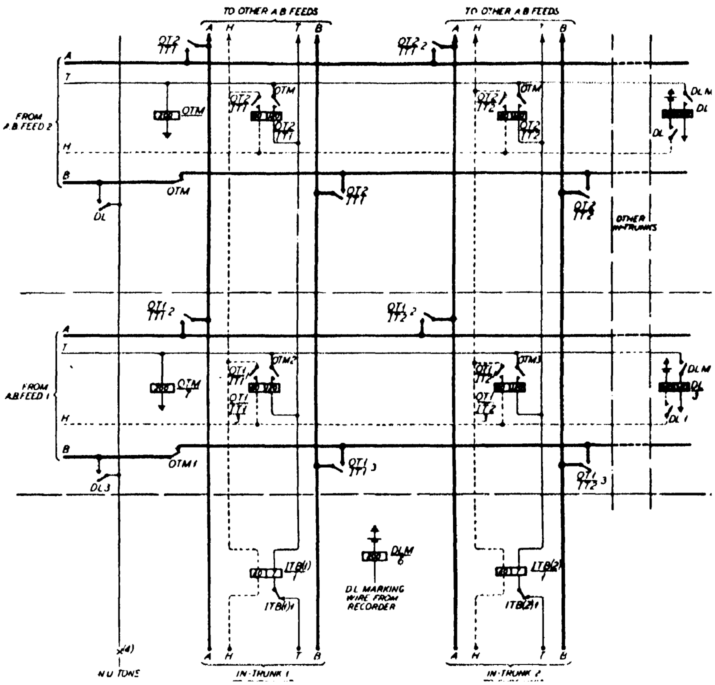


Fig. 734. Relays of Trunk Connecting Group

operate when current is flowing in both the test wire and the hold wire. This differential feature is provided to avoid double in-trunking, which would result if *ITB* disconnected the test wire whilst the recorder was still marking out. Under these conditions the operated *LM* relay in the subscriber's unit would release, and the next available one would operate to cause two in-trunks to be marked. The differential characteristics of *ITB* make it dependent on the cessation of marking. When the recorder completes the marking out, the test wire circuit is disconnected, and *ITB* operates on its 40 Ω coil over the hold wire circuit. ***ITB*1** disconnects the test wire of the in-trunk to busy it. At the end of the call, the removal of the earth from the hold wire in the A and B feed allows relays *OT*/*IT* and

ITB to release, thereby restoring the circuit to normal.

Manual Switchboard. The manual switchboard used in conjunction with a relay P.A.B.X. is of the conventional bridge control type with through clearing. Speaking, ringing, and dialling keys are provided per cord circuit, and, if necessary, facilities are available for the incorporation of a mechanical keysender. The exchange line circuits utilize break jacks with a condensered indicator connected to the inner springs. Each extension appears in the jackfield of the manual board and the extension circuits are so arranged that, when a line is engaged at the manual board, the appropriate busying conditions are applied to the automatic equipment.

It is usual to provide direct access facilities, whereby any extension telephone can reach the public exchange by dialling the digit "9." This necessitates arrangements in the recorder similar to those for "0" level calls.

Standard P.A.B.X.s. Considerable advantages are to be gained by the standardization of the P.A.B.X. equipment at subscribers' premises. Not only does such standardization facilitate the training of maintenance staff, but it also simplifies the supply of spare parts, makes possible bulk orders on the manufacturers' works, and unifies the installation procedure. It is moreover highly desirable that the P.A.B.X. equipment should give uniform service facilities. It was therefore decided in 1938 to produce designs of P.A.B.X. equipment which would meet all but exceptional requirements of the subscribers. The development of the standard schemes was delayed during the war years, but a number of prototype installations have been in use for several years. The final design is at present in the late stages of development.

The new standard P.A.B.X.s employ step-by-step switching principles with 2-motion selectors as the main switching medium. The circuit design and the apparatus used are as far as possible the same as on the standard main exchange automatic equipment. The 2-motion selectors are of the 2000 type and the controlling relays are of the 3000 or 600 type. Most of the circuits are arranged as "jacked-in" units in order to facilitate their removal from the apparatus rack for maintenance work, etc.

There are two basic designs. The first is intended for installations of up to 49 extensions, and is normally used in conjunction with a cordless attendant's cabinet. The alternative design is for installations of from 50 to 1200 lines and works in conjunction with a cord type P.A.B.X. switchboard of conventional design. The trunking arrangements are somewhat different from the P.A.B.X.s described earlier in this chapter, due primarily to the provision of call-back and auto-transfer facilities (q.v.).

49-line P.A.B.X. with Cordless Attendant's Cabinet. There are four models of this small type P.A.B.X. to cater for installations with a total of from 15 to 49 extensions. The extension numbering scheme, the capacity, and the number of connecting circuits provided in the various models are as follows:

Type No.	Exchange Lines	Extensions	Connecting Circuits	Numbering Range
1A	4	15	3	21–35
1B	5	24	4	21–44
2A	7	35	6	21–55
2B	10	49	7	21–69

Fig. 735 gives an outline of the trunking arrangements of this type of P.A.B.X. equipment. Each extension instrument is terminated on a 2-relay line circuit and all extension lines appear on the banks of a number of uniselector linefinder switches. One such linefinder is associated with each connecting circuit (2-motion selector) and one linefinder uniselector is provided per exchange line and "0" level circuit. A common start circuit determines which connecting circuit, exchange line or "0" level circuit is taken into use on any particular call. On the 1A and 1B models the linefinder uniselectors are of the 25-outlet type, but on the two larger models (2A and 2B) 50-point uniselectors are used for the linefinders.

Extension-to-extension Calls. When the extension user loops his line to originate a call, the energization of the line relay transmits a signal to the common start circuit, and at the same time marks the position of the calling line on the linefinder multiple. The start circuit contains a distributor which causes the linefinder of a free connecting circuit to hunt for the calling line. When the extension is extended to the connecting circuit, the caller receives dialling tone, and he then proceeds to step the 2-motion selector vertically in response to the tens digit, and in a rotary direction in response to the units digit of the required extension number. If the required line is free, interrupted ringing is applied in the usual way, whilst ringing tone is returned to the calling extension. If, on the other hand, the called party is engaged, switching does not take place, and busy tone is returned to the caller.

The interrupted ringing is automatically cut off

when the called party replies, and normal central battery transmission is provided for the conversational period. The circuits are designed to give first party release, i.e. the connexion is broken down by the replacement of either the calling or the called party's receiver. If an extension user dials a spare number or a spare level, he receives engaged tone. (No N.U. tone is provided on the P.A.B.X.) If a connecting circuit is seized by a faulty line (or by a subscriber who omits to dial) the circuit is forcibly released after a time interval of 36–72 sec. The line circuit then locks itself out of the system and a common P.G. lamp is lighted. This condition remains until the fault is cleared.

Outgoing Exchange Line Calls. An extension user dials "9" to obtain access to the main exchange lines. The 2-motion selector of the connecting circuit steps to the 9th level in response to this digit, and at the end of the impulse train a signal is extended from the vertical marking bank to the "9" level lead of the start circuit. This start signal is connected via the start distributor to the first free exchange line circuit. The linefinder (*JF*) associated with the selected exchange line now hunts for the originating extension line which is marked by a battery condition applied to the linefinder multiple by the connecting circuit. When the calling extension is seized by the *JF* switch, the loop is extended and the originating extension receives dial tone from the main exchange. The original connecting circuit is now released and is available for use on a succeeding call.

If all exchange lines are engaged, a marking condition is applied through an exchange line "busy chain" to the *LF* banks so that, if an extension dials "9" into any connecting circuit, busy conditions are automatically returned to the caller. The P.A.B.X. operator is normally unaware of the seizure of an exchange line by an extension. She can, however, ascertain which lines are engaged by the depression of a "junction test" key which causes a lamp to light on all engaged junction circuits.

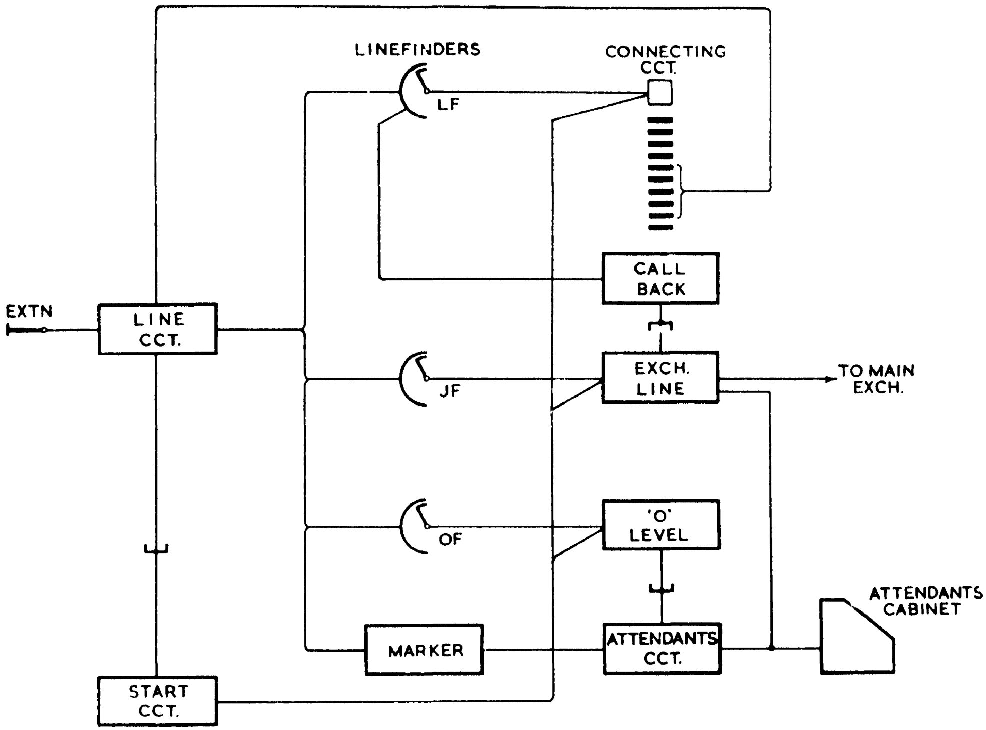


FIG. 735. TRUNKING ARRANGEMENTS OF 49-LINE STANDARD P.A.B.X.

Through clearing from the extension to the main exchange is provided by the disconnexion of the forward loop when the extension user replaces his receiver at the termination of a call. It is proposed, however, that the holding loop be replaced by a 50 c/s a.c. signal applied to the line conductors in parallel. This a.c. signal passes through a differentially connected relay, the connexions

being such that the relay does not operate with equal currents in its two windings. This condition exists for so long as the exchange line is extended through to a group or a final selector at the main exchange or to a manual board relay set.

If the call is to a local number on the main exchange, the removal of the holding loop from the P.A.B.X. allows the switching train to release and, when the exchange line circuit (main exchange) restores to normal, the balanced impedance of the − and + lines is replaced by the unbalanced line circuit (i.e. earth on the + line, battery through line relay on − line). The unbalanced condition now allows the a.c. relay in the exchange line circuit at the P.A.B.X. to operate, and this in turn releases the connexion at the P.A.B.X. If, on the other hand, the call is to a manual board circuit on which manual hold is provided, the switching train at the main exchange is under the control of the answering plug at the manual switchboard. The maintenance of the balanced impedance condition prevents the operation of the a.c. relay and thereby holds the connexion at the P.A.B.X. This "extended hold" feature overcomes the well-known disadvantage in P.B.X. working that a follow-on call from a second extension might be mis-routed due to the seizure of the exchange line before the exchange equipment has been released from the preceding call.

Facilities are provided in the design of the P.A.B.X. circuits for barring direct access to the exchange lines from any particular extension. In such cases, exchange calls can only be set up with the assistance of the P.A.B.X. operator.

Call-back Circuit. By means of a press button an extension user can hold an exchange line call and use his telephone to make enquiries from other extensions. The extension user can subsequently return to the exchange call or can transfer the call to another extension. This operation can be repeated as often as desired on the same call and without assistance from the attendant. The call-back facility is obtained by the operation of a press button on the extension instrument which connects earth to the calling loop. This earth signal operates a differential relay in the exchange line circuit. On receipt of this signal a holding loop is applied to the main exchange circuit, and the extension loop is extended to a free "call-back" circuit associated with the exchange line circuits.

This call-back circuit appears, in exactly the same way as an extension line, on the banks of the linefinder associated with the connecting circuits. At the same time a signal is applied to the "line start" lead of the common start circuit so that the first free connecting circuit hunts for the marking condition on the *LF* bank. When the linefinder seizes the calling line, the extension is extended through the exchange line and call-back circuits to the connecting circuit, and tone is returned to indicate that dialling may proceed. The caller now dials the required extension, and when he has completed his enquiry he can return to the exchange line by operating the press button again. This second signal disconnects the holding loop from the call-back and connecting circuits, thereby allowing these circuits to release. At the same time the holding coil on the exchange line circuit is replaced by the extension loop, and the extension user is again associated with his correspondent on the exchange line. If all call-back circuits are engaged when the extension operates his press button, the exchange line circuit causes the supervisory lamp in the attendant's cabinet to flicker. The operator can then enter the circuit and assist the extension user by calling the required extension in the normal way.

In some cases it may be desirable to switch the exchange line to a second extension. This "automatic transfer" facility is obtained by the call-back procedure described above. The first extension, after establishing a call to the main exchange, can call any other extension on the P.A.B.X. by operating his instrument press button and by dialling the extension number over the call-back and connecting circuits. When the second extension replies, the first extension replaces his receiver. The disconnexion of the loop from the first extension sets up conditions in the exchange line circuit which cause the linefinder (*JF*) associated with that circuit to hunt for the extension number which has been set up over the call-back circuit. Control of the call is now vested in the new extension, and the call-back and connecting circuits are released.

"0" Level Calls. When an extension user dials "0," the wipers of the connecting circuit selector are stepped to the 10th level and a signal is applied via the vertical marking bank to the "0" level start lead of the common start circuit. This causes the seizure of the first free "0" level circuit and the linefinder (*OF*) of this circuit hunts for the marking condition applied by the connecting circuit which indicates the position of the calling extension. When the calling line has been extended to the "0" level circuit, the initial connecting link is released and the supervisory lamp in the attendant's cabinet (which is associated with the "0" level circuit) is made to flash at "flicker" speed. Ringing tone is now returned to the caller. The attendant replies by throwing the associated

speaking key, which extends the caller to her telephone set and extinguishes the calling lamp.

If the caller requires a call via the main exchange, the attendant operates the exchange test key which causes the supervisory lamps of all engaged exchange line circuits to glow. After selecting a disengaged line, the attendant seizes this line by operating the associated speak key. She can now set up the call by means of the dial on her position which can be associated with the exchange line by the throwing of a common dial key. During the setting up of the call the extension can either remain on the line or replace his receiver until he is rung. The attendant's cabinet is equipped with a group of digit keys (1, 2, 3 . . . 0) in addition to the normal dial. When the main exchange connexion has been established, the operator can, if necessary, recall the originating extension by keying up the number of the extension and then retire from the circuit by restoring the speak key.

A marker unit is associated with the attendant's circuit. This unit contains a number of relays which receive signals from the digit keystrip and apply suitable marking conditions to the required extension position on the linefinder banks. (Note that the attendant does not use her dial on setting up calls to extensions.) The linefinder (*JF*) associated with the exchange line circuit now searches for the marked extension number. The extension is automatically rung by the exchange line circuit which switches through the call when he replies. If, on the other hand, the extension is waiting on the line, the "0" level circuit is held by his loop until the exchange line uniselector takes over. The "0" level circuit is now released for use on further calls.

Incoming Exchange Calls. On incoming calls a relay in the exchange line termination operates to the ringing current from the public exchange and lights the calling lamp on the attendant's cabinet. The operator answers by throwing the speaking key. (The circuits are so arranged that only one exchange line circuit can be connected to the attendant's circuit at any one time.) The throwing of the speak key trips the ringing and places the operator in communication with the caller. The operator now ascertains the extension number required and sets up the call to that extension by operating two digit keys in succession. The signals from the digit keys are applied to the marker circuit, which in turn marks the required extension line on the linefinder multiple. The linefinder (*JF*) associated with the exchange line circuit is now caused to hunt for the extension line, and if this line is free, automatic ringing is applied to call the extension. Having keyed up the extension number, the operator can retire from the circuit by restoring the exchange line speak key.

If, on the other hand, the required extension is engaged, the linefinder (*JF*) associated with the exchange line camps on the extension number and waits until the line becomes free before ringing the extension and switching through the call. During the waiting time the supervisory lamp associated with the exchange line flashes at busy speed to remind the attendant that the caller is waiting. Unless the waiting period is very prolonged, it should not be necessary for the operator to take action on such calls. The exchange line is automatically switched to the required extension as soon as this extension becomes free. If in the meantime the calling subscriber tires of waiting and abandons the call, the exchange line is automatically freed and the extension will not be called. The common start circuit provides a series of test pulses in rotation to each of the exchange lines to ensure that no two circuits in the "camp on busy" condition test to the same extension concurrently.

Call-back and auto-transfer facilities are available to the extension user on incoming exchange calls. The procedure is identical to that described for outgoing calls. It is also possible for the extension user to recall the operator at any time during the progress of a call by operating the telephone press button twice in succession. This causes the supervisory lamp associated with the exchange line to flicker, thereby drawing the attendant's attention to the recall signal. (This operator recall facility is also available on outgoing calls and can be used in place of the recall facility if an extension user wishes to pass information to the attendant during the progress of a call.)

The "a.c. clearing" feature described in connexion with outgoing calls is also available on incoming calls to the P.A.B.X. The provision of this facility makes it possible to place the holding of the connexion at the P.A.B.X. under the control of the main exchange calling subscriber, thereby obviating the necessity for supervision at the P.A.B.X. manual board. On all incoming calls the connexion at the P.A.B.X. is held until the switching train at the main exchange has restored, i.e. until the exchange line circuit reverts to the unbalanced earth and battery condition.

Facilities are provided for the attendant to enter any established conversation for the purpose of offering a trunk call or for any other reason. An interrupt key is provided on the attendant's cabinet, and by throwing this key the operator can obtain access to any engaged line. When any established call is interrupted in this way, a warning

tone (a ticking tone) is given to the parties concerned to indicate that the operator is listening. The operator also has facilities for splitting any extension-to-exchange call so that she can speak to one or other of the parties at will.

Night Switching. Night service is provided by operating a special locking key on the attendant's cabinet. One or more continuous ringing bells are fitted at selected points in the subscriber's premises, and, when the night switching key is thrown, an incoming call over an exchange line causes these bells to ring. The incoming call can then be answered from *any* extension by the dialling of digit "8." If necessary a call can be transferred to any other extension by using the call-back and auto-transfer facility. It will be noted that, under night service conditions, all exchange lines are available for the receipt of incoming calls. Normal extension-to-extension service on a dialling basis is, of course, also available, and any extension can obtain access to the exchange lines by dialling "9" as during the day period. Where only one particular extension is available to receive calls under night service conditions, the circuits provide for a ticking tone to be applied if an incoming call arrives when the extension is in use.

Miscellaneous Facilities. The standard P.A.B.X. equipment also provides the following miscellaneous facilities:

(*a*) The release of an exchange line by the operation of a release key in the attendant's cabinet.

(*b*) There is a limited capacity for the accommodation of "manual extensions." Such extensions are not provided with a dial and can only initiate calls with the assistance of the operator. A special "manual extension circuit" is interposed between the extension line and the normal line circuit to give this facility.

(*c*) An urgent alarm is given in the event of a mains failure. (Such a failure affects the a.c. clearing signal.)

(*d*) An urgent alarm is also given after a delay of about 30 sec if there is a failure of the ringing supply at the P.A.B.X.

(*e*) Forced release is applied to any P.G. conditions as described previously. After a delay period of some 30 sec, a P.G. condition operates a deferred alarm lamp in the attendant's cabinet.

(*f*) If an extension should attempt to transfer an incoming call to another extension which is busy or does not reply, the exchange line circuit automatically reverts to the condition of an ordinary call that has been prematurely abandoned.

(*g*) The marker circuit associated with the attendant's cabinet gives facilities for the rapid consecutive testing of alternative extension lines.

Small P.A.B.X. with Cord Type Manual Board. The small P.A.B.X. described in the preceding paragraphs provides for a limited number of inter-switchboard tie lines. Whilst this will meet the requirements of the majority of subscribers, conditions may occasionally arise where the number of tie circuits or other requirements make it desirable to provide a cord type switchboard of more conventional design. With this board an answering lamp and jack is provided per extension instead of the two "0" level circuits provided on the cordless board.

When an extension dials "0" the stepping of the connecting circuit selector to the 10th level energizes a "lamp lighting circuit" which in turn causes the lamp associated with the calling extension to glow. On a cord type switchboard, the operator rings the required subscriber manually instead of the automatic scheme provided on the cordless board. The "camp on busy" feature is not available, the operator supervising the calls to engaged extensions in the normal manner. A follow-on call trap is provided on exchange line calls, and on calls to or from inter-switchboard lines (which are set up by the operator). Press button operator recall facilities are available.

50–1200-line Standard P.A.B.X. Somewhat different trunking principles are utilized on the larger type standard P.A.B.X. A 3-digit extension numbering scheme is used when the total number of extensions does not exceed 500. In these circumstances the calls are established through one group selector stage and a final selector stage. By the provision of a group of 2nd selectors, and the adoption of a 4-figure numbering scheme, the capacity can be increased to 1200 extensions. Fig. 736 shows typical trunking arrangements. The extension telephones are terminated on line circuits in the usual way and are divided into groups, each group being served by a 50-point linefinder of the uniselector type. When an extension receiver is lifted, the linefinder associated with a free "local" 1st selector hunts for the calling line and, when the line is switched to the selector, dial tone is returned to the caller. The extension then proceeds to dial 3 or 4 digits as may be required to position the group selectors and final selectors of the switching train. Direct access to the exchange lines is obtained via level 9 of the 1st selectors, facilities being provided for barring direct access from any particular extensions.

The P.A.B.X. operator is obtained by dialling "0." There are two alternative methods of routing such calls. In some cases level 0 of the 1st selectors is trunked to "0" level jacks and answering lamps on the manual switchboard in substantially the same

way as "0" level calls are dealt with on a public automatic exchange. As an alternative to this method, calling lamps may be provided with the extension jacks on the manual switchboard. The dialling of the digit "0" causes the 1st group selector to step to the 10th level and to seize a lamp lighting circuit. This lamp lighting circuit in turn causes the lamp associated with the calling extension to glow.

Incoming exchange calls are normally received at the manual position and are connected by means dialling tone and can proceed to dial any other extension number. The call-back circuit can be released by a second operation of the press button which causes the first extension to be reconnected to the exchange line circuit. Auto transfer is not provided, but if it is desired to transfer a call to another extension the operator is recalled by a double depression of the press button and is requested to transfer the call. The same operator recall signal can be used at any time if the extension wishes to attract the attention of the operator.

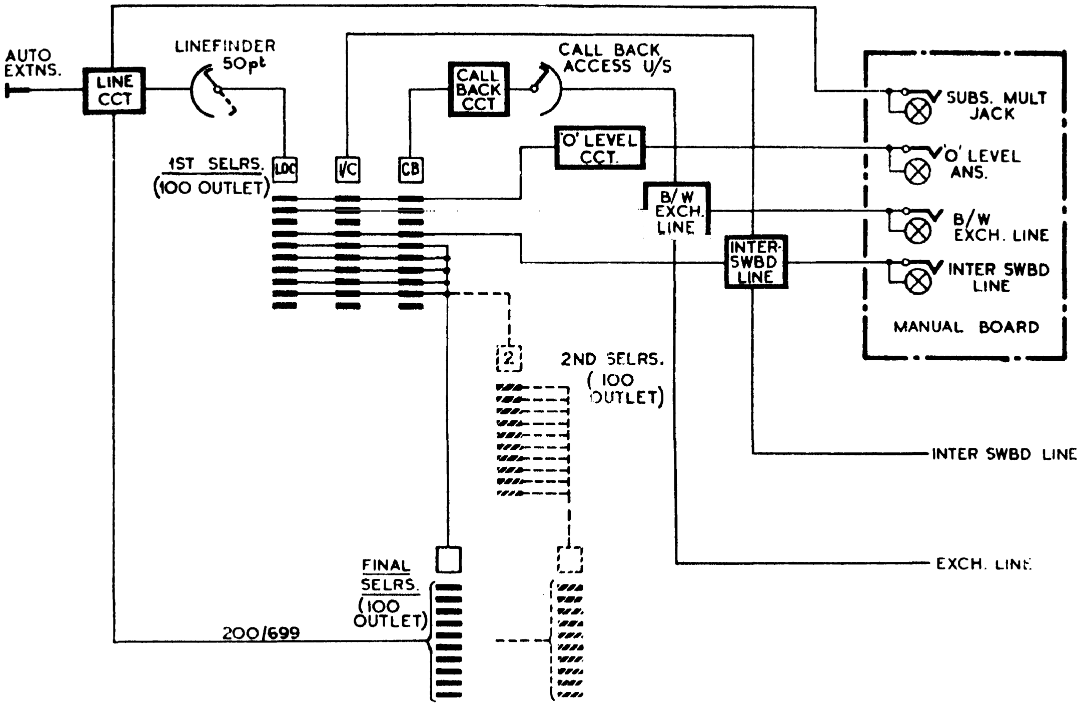


FIG. 736. GENERAL TRUNKING ARRANGEMENTS OF LARGE TYPE STANDARD P.A.B.X. WITH A CAPACITY OF 50–1200 EXTENSIONS

of plugs and cords to the required extension circuit. Manual ringing by the operator is required for such calls, whilst if the required extension is engaged, the usual engaged test appears on the bush of the jack.

Call-back facilities are provided by the use of a press button at the extension instrument as in the smaller installations. The operation of the call-back press button transmits an earth signal through the cord circuit to the exchange line terminating relay set. Receipt of this signal causes a call-back access uniselector (associated with a free call-back 1st selector) to hunt for the exchange line and to extend the extension through the exchange line circuit and the call-back circuit to a special 1st selector. The extension now receives

The recall signal causes the supervisory lamp of the appropriate cord circuit to flash continuously until attention is given by the operator.

Normal P.B.X. night service facilities are available, i.e. the extensions selected for night service are connected directly to the exchange lines by means of cord circuits and special night service jacks on the switchboard. In some cases it is possible to fit a subsidiary switchboard for receiving calls during night service conditions. The calls can then be extended from this switchboard to the required extension by dialling through the P.A.B.X. equipment.

Inter-switchboard lines appear on the manual board in the same way as the exchange lines and extensions. Facilities are provided for barring

communication between inter-switchboard lines and the exchanges lines if required. Call-back facilities are not provided on calls via tie circuits, but, if such calls are routed via the manual board, a single operation of the press button at the extension instrument provides an operator recall signal by causing the cord circuit supervisory lamp to flash until the operator replies. Access to the inter-switchboard tie lines can be obtained from the levels of the 1st selectors (usually 6, 7, or 8). This facility is not, however, available on long tie lines where generator signalling is employed.

The circuits are designed for through clearing to the public exchange when the local extension replaces his receiver. If, on incoming calls, a second call arrives before the previous call has been disconnected at the P.A.B.X. manual board, the cord circuit supervisory lamp flashes to indicate to the operator that another call is awaiting attention, and the exchange line is isolated from the extension circuit to prevent unnecessary disturbance. On the larger switchboards, facilities are available for the provision of multiple answering equipment on the exchange lines.

The automatic equipment is mounted on standard apparatus racks of the open type. These racks are 7 ft high and are of a uniform width of 4 ft 6 in., with the exception of the line relay and final selector rack which is 3 ft 6 in. wide. The selectors, relay sets, etc., are jacked in and utilize standard automatic exchange components.

EXERCISES XXIV

1. What do you understand by the terms "calling party release" and "first party release"? What are the merits and limitations of these two principles when applied to local calls at a P.A.B.X. installation?

2. Why is it usual to provide "through clearing" on extension to main exchange calls from a P.A.B.X.? Describe any difficulties which may result from this method of working.

3. What do you understand by the following terms which may be applied to a P.A.B.X.?

 "Operator Recall."
 "Call Back."
 "Auto Transfer."
 "Preference Facility."

4. Give a trunking diagram of a 40-line P.A.B.X. where the connexions are established via 22-outlet uniselectors. Explain exactly how the uniselectors are positioned in response to the digits dialled by an extension user.

5. In a certain P.A.B.X. the main switching circuits provide "Forced Release" conditions if the equipment is held unnecessarily. The forced release signal is the disconnexion of the "backward holding" earth on the *P*-wire. Show how it is possible to design a 2-relay line circuit which gives all the normal facilities of such a circuit and will also switch the line to the manual board under forced release conditions.

6. Give simple circuit elements to show how it would be possible to modify the circuit of an ordinary main-exchange final selector so that it could be used to give "preference" facilities at a P.A.B.X. It may be assumed that the preference signal is a momentary earth (applied from a press button) on the calling loop from the extension.

7. A subscriber's installation consists of 3 telephone instruments (in the same building) and a single exchange line. Design a simple automatic switching circuit which could be installed at the subscriber's premises to provide:

 (*a*) communication between the 3 instruments,
 (*b*) access to the exchange line from any instrument,
 (*c*) for all incoming calls to be received on one particular instrument.

8. Describe, with the aid of suitable circuit elements, how an "A and B feed" circuit at a relay P.A.B.X. is switched to the required subscriber's line.

9. Give a trunking diagram of the proposed standard 49 line P.A.B.X. Describe what happens when a subscriber dials "9" to obtain access to the main exchange. What are the special merits of this method of working?

10. Describe, with the help of block diagrams, how it is possible to provide "Call Back" and "Auto Transfer" facilities at a 3-digit P.A.B.X. which employs group and final selectors of the 2-motion type.

CHAPTER XXV

MISCELLANEOUS FACILITIES

Equipment is provided in a modern automatic exchange for a wide range of miscellaneous facilities. Some of this equipment is required to provide special services to the subscriber, whilst other apparatus is designed specially to maintain a watch on the quality of service, to provide for the testing of the main switching equipment, and so on. It is not possible in the space available in this volume to give a comprehensive description of these many facilities, but a selection of the more common or more important miscellaneous circuits is given in this chapter.

Test Switching Train. Although facilities are available for connecting to subscribers' lines at the M.D.F., the testing of subscribers' circuits in automatic exchanges is carried out mainly through a special train of *test selectors* accessible from the test desk. The general arrangements for a 4-digit exchange are shown in Fig. 737. One Test Final selector is provided for each final selector group. This switch may be of the 100- or 200-outlet type to correspond with the regular final selectors, and is usually mounted in the 10th position of the last shelf of the F.S. multiple. One or two Test Selectors (depending upon the number of simultaneous tests required) are fitted on a convenient relay set rack and give access to all the Test final selectors in the exchange. These test selectors respond to the first two digits of the subscriber's number and contain all the relays necessary for the subsequent control of the Test Final selector.

Access to the Test Selectors is obtained via a relay group from jacks multipled along the test desk suite. "Engaged" and "Hold" lamps are associated with each outgoing line to a Test Selector whilst two locking type plunger keys are provided to change over from stepping to test conditions and for controlling the operation of the subscriber's cut-off relay.

Test Selector Circuits. The insertion of a test plug into the "operate and test" jack energizes relay *BR* (Fig. 738), which at ***BR*3** polarizes the *PR* relay and gives a continuous glow on the busy lamps of all multiple appearances. The Test Selector (Fig. 739) is seized by the loop from the test cord and relays *A* and *PC* operate in series. ***A*1** operates *B* and relay *C* operates in series with the vertical magnet when the first digit is dialled. At the conclusion of the first impulse train, *C* releases and at *C*4 operates *E* to prepare the rotary magnet circuit at ***E*2**. During the second train of impulses, *C* again operates and at ***C*3** energizes relay *EA*. At the end of the second train, *C*4 disconnects the hold circuit for *E*. During the release lag of *E*, a testing circuit to the Test Final selector is provided by ***E*3**. *G* operates if the selector is engaged (200 Ω battery on *Z*-wire). ***G*2** gives busy tone whilst ***G*7** and ***G*8** reverse the lines. The reversal operates *PR* in the jack circuit (Fig. 738) and ***PR*1**, in turn, causes the busy lamp

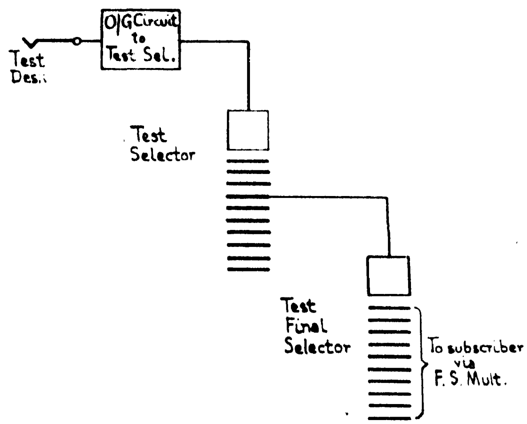


Fig. 737. Trunking Arrangements of Test Switching Train

to flash on the position from which the call is originated.

If the Test Final selector is free, relay *H* operates on the release of *E*4. ***H*2** operates *FS* whilst ***H*4** prepares the circuit to route the third train of impulses to the final selector vertical magnet. During the third impulse train, *C* again operates and releases *EA* at ***C*4**. At the end of the train, *C*4 in releasing again energizes *E*. ***E*2** now changes over the impulsing circuit to the final selector rotary magnet via the *R* wiper of the test selector. The fourth digit is received by the final selector rotary magnet and *EA* again operates from the ***C*3** contact during the energization of *C*. At the end of the final train, *C* in releasing operates *RC* at *C*3. ***RC*5** provides an impulsing circuit to the final selector rotary magnet independent of ***E*2** and *G*5 so that the wipers can be stepped over the level by dialling single digits. *C*1, in releasing,

connects the *PT* relay to the *P*-wire to test the subscriber's line circuit. If the subscriber is engaged, *PT* fails to operate and on the release of *E* (disconnected at *C*4) relay *G* operates to give the engaged tone and lamp flash.

If the subscriber's line is disengaged or becomes free whilst the test circuit is held, *PT* operates and at ***PT*1** busies the line against intrusion. ***PT*1** also releases *G* if the latter has operated. ***PT*2** provides an alternative hold circuit for *PT* against the operation of ***PT*1**. If it is desired to test the next line, a single digit is dialled and *C* in operating releases *PT*. When *C* again releases the testing circuit is restored.

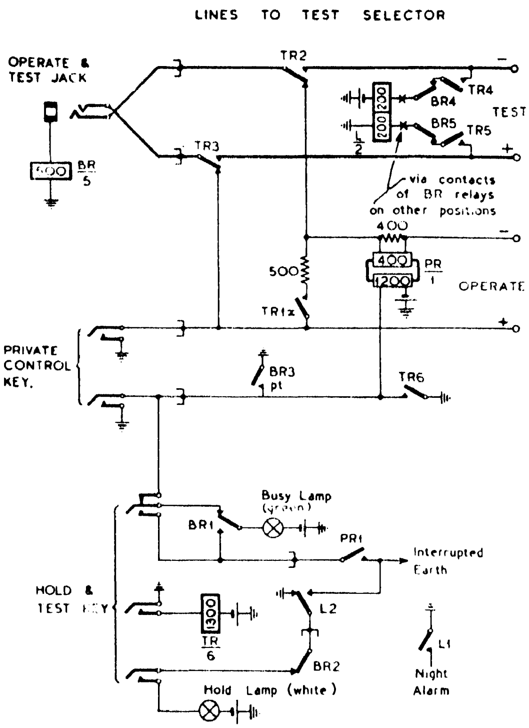


Fig. 738. Outgoing Circuit from Test Desk to Test Selector

The circuit is now set up and the subscriber's line is extended to the test plug by the operation of the "Hold and Test" key. *TR* (Fig. 738) operates and at ***TR*1** provides a holding loop to the test selector in readiness for the switching of ***TR*2** and ***TR*3**. If during testing it is desired to release the subscriber's cut-off relay (e.g. to make an originated call from the subscriber's line), the Private Control key is operated. This returns an earth on the positive wire and releases relay *PC* in the test selector. *PC*1 in turn breaks the holding circuit on the *P*-wire.

Tests may be made on consecutive lines by dialling single digits. Relay *C* operates and releases *PT* at **C1**. At the end of each digit, *C* releases and the testing circuit is restored. Provision is made for an alarm to be given if a subscriber's line is held by the "Hold and Test" key after the withdrawal of the test plug. In these circumstances *TR* is operated and *BR* is released, thereby placing the *L* relay across the test pair. *L* operates when the subscriber lifts his receiver and at ***L*2** applies a flashing signal to the Hold lamps, whilst ***L*1** gives an audible alarm.

Trunk Offering. Facilities are provided at nearly all exchanges whereby a telephonist can offer an incoming trunk call to a subscriber who may be engaged on a local connexion. In the British Post Office system a separate selector train is used for trunk offering (except at certain U.A.X.s). This switching train is not intended to carry ordinary conversational traffic, but is used merely to ask the subscriber to clear down from the local call if he is agreeable to accept an incoming long-distance call. The trunk offering circuits are also used for the verification of a calling subscriber's number from the automanual switchboard.

The trunk offering circuits appear in the outgoing multiple of the automanual switchboard and are multipled over all the positions, including the Enquiry positions. The circuits give access to trunk offering selectors which are, for convenience, usually accommodated on a miscellaneous relay set rack. The trunk offering selector accepts the first two digits (i.e. both the vertical and rotary action are under the control of the operator's dial) and switches to a trunk offering final selector. The trunk offering final selector is mounted along with the test final selector at the end of the final selector bank multiple, and, by stepping this selector vertically and then in a rotary direction, the operator can establish connexion to any required line—irrespective of whether or not the line is engaged. In a 4-digit exchange, the operator dials the full number of digits but, where a 5-digit scheme is in use, the lines to the trunk offering selectors are divided into separate groups so that each selector behaves as a second (and third) numerical selector. This does, of course, involve the provision of a separate group of trunk offering circuits for each working 1st selector level of the exchange. Normally only one trunk offering circuit is provided per final selector group. The trunk offering selectors which give access to these switches are provided on the basis of the anticipated traffic. In this connexion it is assumed that the average holding time of the trunk offering circuits will be 1 min, that 5 per cent of the

incoming long-distance calls will require trunk offering facilities, and that circuit provision will be required for verification of the calling subscriber's number on 5 per cent of the busy hour demand calls.

Trunk offering is also available on all junctions from a parent exchange which is directly connected to a U.A.X., or is indirectly connected via another U.A.X. There are some cases where the trunk offering facilities are not available, e.g. where the parent exchange is indirectly connected via a remote non-director exchange. The volume of trunk offering traffic at U.A.X.s is generally so small that a separate switching train is not justified and arrangements are made to provide trunk offering facilities over the normal group and final selectors.

Trunk Offering Selector Circuits. Fig. 740 shows the circuit arrangements of the trunk offering selector and trunk offering final selector. As with the test switching train, all the controlling relays are located in the trunk offering selector, the magnets of the final selector being energized over additional wipers (V, R, and Z). When the circuit is seized by an operator, relay A operates to the loop extended from the manual board relay set and at **A1** operates relay B. (Note that relay C is not pre-operated.) The first impulse train is directed via A1, relay C, **B3**, G3, RC5, E3, and H3 to the vertical magnet of the trunk offering selector. Relay C operates at the first break and releases during the interdigit pause. At the end of the first train of impulses, relay E operates from the earth at **B4** via C3 and EA3. **E3** changes over the

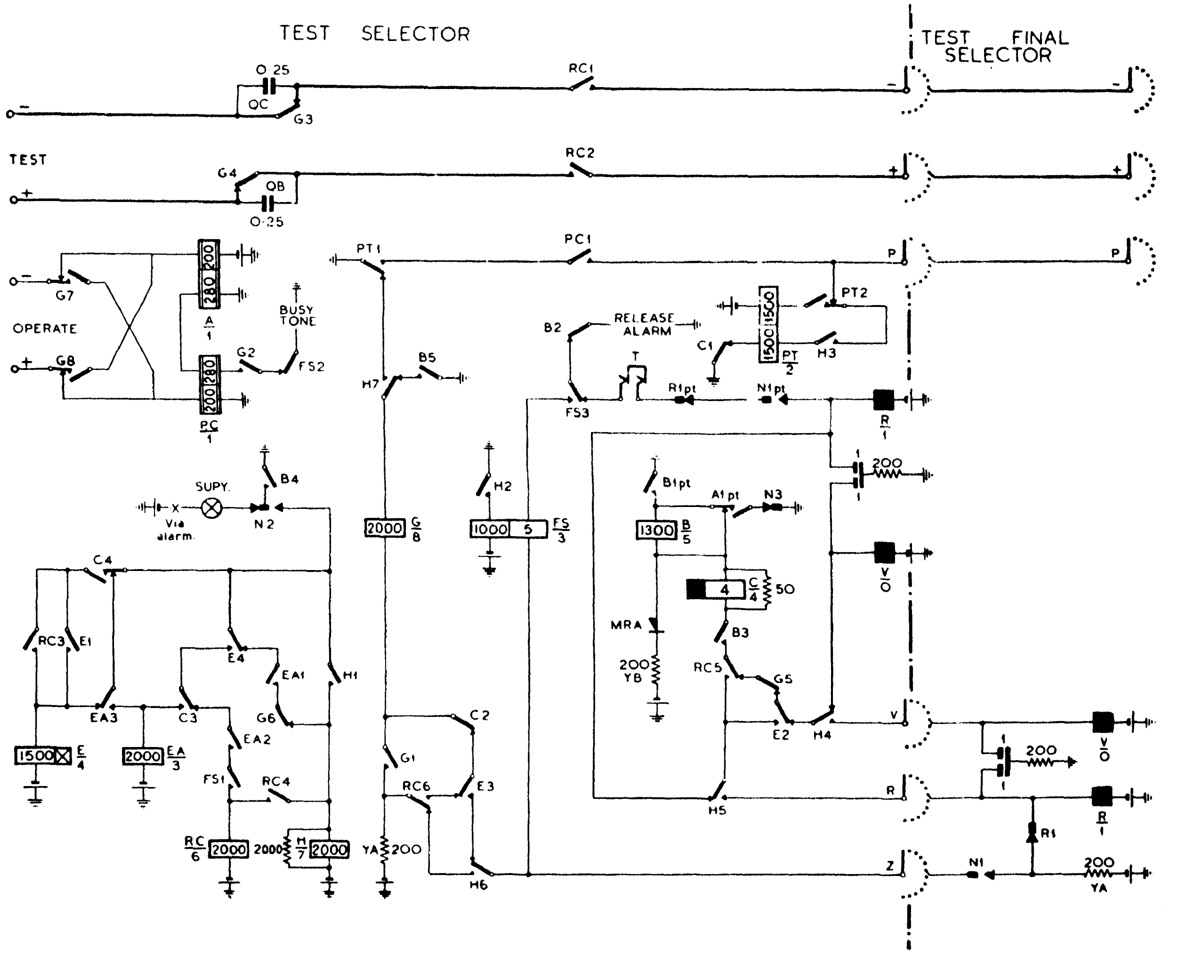


FIG. 739. TEST SELECTOR AND TEST FINAL SELECTOR CIRCUITS

impulsing circuit to direct the next train of impulses to the rotary magnet. Relay *C* again operates during reception of the second digit and **C2** closes a circuit for relay *EA*. At the end of the rotary train, *C*3 disconnects the hold circuit of the slugged relay *E*. During the release lag of *E*, a circuit is completed for relay *G* from the earth at **B5** to the *Z* wiper of the selector. If the trunk offering final selector is engaged, there is a battery condition on the *Z*-wire which allows relay *G* at **C3** breaks the holding circuit of relay *EA*. At the end of the train the release of *C* again completes a circuit for relay *E* (via *EA*3) and contact **E3** directs the next train of impulses to the rotary magnet of the trunk offering final selector. **E1** operates relay *PT* in readiness for the testing of the subscriber's line. Relay *C* operates during the fourth train of impulses, and at **C2** re-operates relay *EA*. At the end of the train the release of *C* completes a circuit for relay *RC* (via **E4**, *C*2,

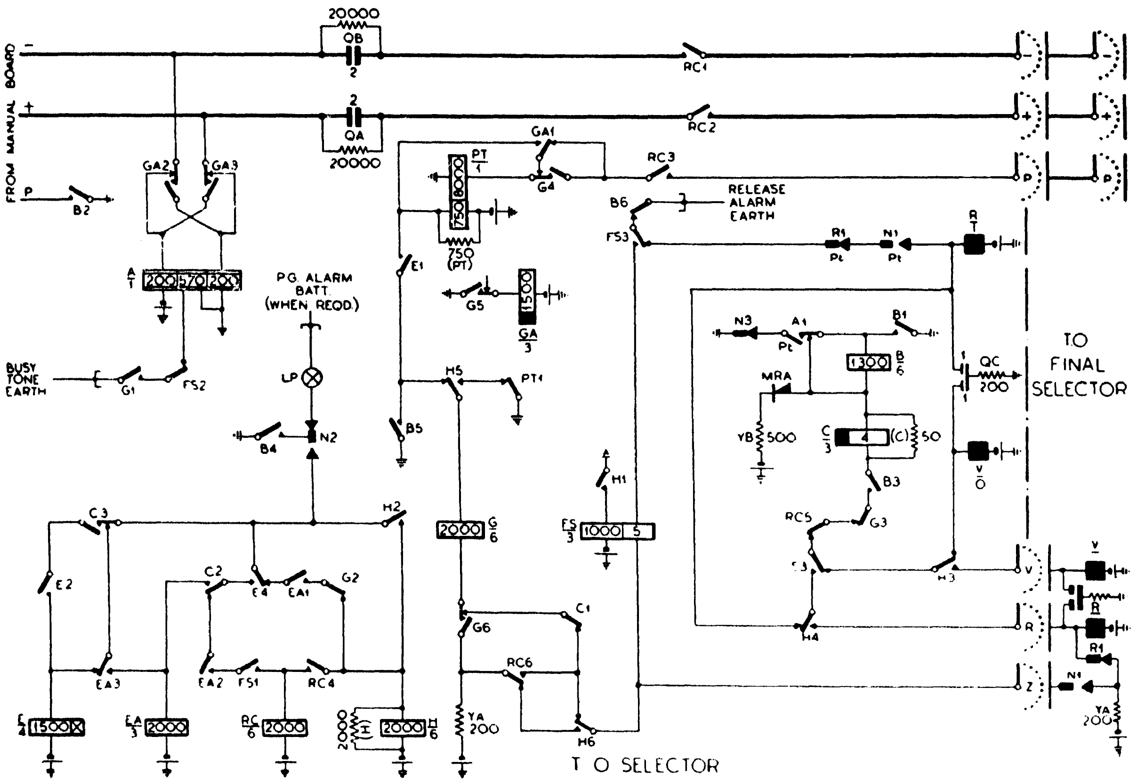


FIG. 740. TRUNK OFFERING SELECTOR AND FINAL SELECTOR CIRCUITS

to operate. **G1** returns busy tone to the operator, whilst **G5** operates *GA* to darken the supervisory lamp.

If the trunk offering final selector is free, the absence of battery on the *Z*-wire prevents the operation of relay *G*, and, on the subsequent release of relay *E*, a circuit is provided for the operation of relay *H* (via *E*4, **EA1**, and *G*2). *H* now holds for the duration of the call via its own contact **H2**. **H1** energizes relay *FS*.

The third train of impulses is extended via **H3** and the *V* wiper of the trunk offering selector to the vertical magnet of the final selector. Relay *C* operates as before during the impulse train, and **EA2**, and **FS1**). **RC1** and **RC2** connect the operator to the subscriber's line irrespective of the engaged condition.

RC3 connects relay *PT* to the *P*-wire of the subscriber's line circuit. If the line is disengaged, the battery potential on the *P*-wire provides a holding circuit for *PT* before the initial operating circuit is broken at *E*1. If, on the other hand, the subscriber's line is engaged, *PT* releases when relay *E* restores and at *PT*1 provides an operate circuit for relay *G* to the battery at resistor *YA*. **G5** operates relay *GA* and **GA2** and **GA3** darken the supervisory lamp of the calling cord at the manual position.

When the operator withdraws her plug from the trunk offering jack, the release of relays A and B connects earth to the Z-wire of the final selector via the 5 Ω coil of relay FS. The final selector now drives home, relay FS holding until the final selector is normal. Ultimately the restoration of $FS3$ completes the release circuit of the trunk offering selector.

Routine Testing. In a manual switching system any service difficulties due to plant defects are readily observable by the telephonist who completes and monitors the call. In an automatic switching system, on the other hand, plant faults, especially on the common switching circuits, can cause considerable difficulties, and there are no means of drawing attention to such faults other than by complaints from the subscribers. Even when faults are reported by the subscriber, it is not easy to trace the cause of the difficulty unless the faulty connexion is held. Such a procedure is not practicable in a large number of cases (e.g. when the subscriber has only one exchange line) and in any case it is generally inadvisable to expect such a degree of co-operation from the telephone user.

The only alternative is to provide suitable equipment at the exchange for the functional testing of the apparatus at regular intervals in order to verify that the circuits are in fact performing satisfactorily. Such tests are an important part of the routine testing organization at any automatic exchange. Functional tests, when properly organized and conscientiously carried out, can do much to minimize the delay in the clearance of plant faults and so improve the general standard of service of the exchange.

Functional testing can be designed either on the basis of testing each component selector, etc., individually, or it can take the form of artificial traffic through the exchange, i.e. the functioning of the exchange as a whole is verified. In the British Post Office the routine testing procedure is based on the former principle, i.e. it relies upon suitable functional tests of each individual component. These functional tests are supplemented by visual examination, mechanical and electrical checks, and so on.

The tests can be applied either:

(*a*) Automatically by the circuit itself when it is taken into use for ordinary traffic.

(*b*) By the incorporation of testing facilities in the automatic switching circuit so that, by the operation of certain keys, plugs, etc., the maintenance man can cause the selector to operate as on a normal call.

(*c*) By the provision of small manual test boxes (or testers) which can be temporarily connected to each selector as required for the carrying out of functional tests.

(*d*) By the provision of centralized routining equipment which can obtain access to all the selectors of a given type.

The principle of designing switching circuits so that they will carry out certain tests before completing a call (*a*) has not been used to any great extent in the British Telephone System, although it is an important feature of the systems used by some other telephone administrations. The tests which can be carried out in this manner are usually limited to simple continuity tests of the speaking and control wires, and cannot readily be adapted for the testing of selector wipers,

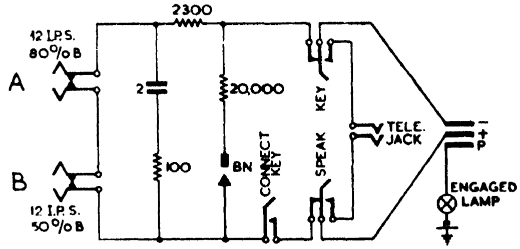


FIG. 741. MANUAL TESTER FOR ROUTINING OF GROUP SELECTORS

control relay contacts, etc. There is nevertheless a growing tendency towards self-testing circuits.

The provision of routine testing equipment as an adjunct to the main switching equipment is particularly applicable to apparatus such as linefinders where one test circuit per linefinder group can be provided at reasonable cost. In other circumstances functional tests are applied either by means of manual testers or by automatic routiners. There is a large number of such testers and routiners, and it is possible in this volume to consider only one example of each type.

Routine Test Box for Group Selectors. Fig. 741 shows the circuit of a test box suitable for carrying out simple stepping tests on group selectors. The equipment is mounted in a small wooden box with two dials, a battery plug and a three-way plug and cord which can be inserted as desired into the test jack of any group selector. The dials can be associated with the incoming — and + wires of the selector by the operation of the "connect key." The loop formed via the impulse contacts of the dials now seizes the selector, and the switch can be stepped vertically by using one or other of the two dials on the test box. Both dials are regulated to give an impulse frequency of 12 I.P.S.

Dial A is adjusted to give an 80 per cent break ratio, and this ratio in conjunction with the 2300 Ω series resistor simulates long line impulsing conditions. Dial B is adjusted to give an output impulse of 50 per cent break ratio, and the off-normal contacts of this dial (BN) place a 20 000 Ω shunt across the loop during impulsing. The combination of low break ratio and shunt resistance simulates leaky line conditions. It is usual to test the operation of the switch by stepping the wipers to the first and then to the 9th level under each of the two extreme line conditions.

An engaged lamp connected to the P-wire of the selector glows if the circuit is engaged, thereby providing a warning signal against the use of the tester until the selector becomes free. Listening tests can be made by operating the speak key and by plugging a portable telephone into the test box. Group selector test boxes, which are intended for use on 200-outlet group selectors, are provided with additional keys by means of which it is possible to busy either the odd or even outlets. By the use of these keys it is possible to verify that the selector will switch satisfactorily to either outlet.

Automatic Routiners. Where there is a large amount of apparatus of the same type, routine testing by manual methods absorbs a considerable amount of engineering time. In these circumstances it is usual to provide automatic routiners which are specially designed to apply a number of functional tests to the equipment and to provide alarm conditions should a fault be found. The routiners are necessarily somewhat complex. This is due partly to the large number of tests provided, and partly to the fairly elaborate circuit arrangements which are necessary to obtain access as required to the selectors, etc., which are to be tested. The cabling of the access circuits is also fairly extensive, and the comparatively high cost prohibits the use of automatic routiners in the smaller exchanges.

The basis of provision of routiners depends upon the type of equipment to be tested. In certain special cases (e.g. directors, A-digit selectors, and 1st code selectors) automatic routiners are provided irrespective of the size of the exchange. Group selector routiners, on the other hand, are provided only if there are more than ten racks of such selectors at the ultimate date. Similarly, final selector routiners are restricted to exchanges with eight or more racks of selectors. Generally speaking, there is only one routiner of each type in a particular exchange, although two routiners are sometimes provided for group selectors and 1st code selectors in very large exchanges.

The testing and control equipment of the routiner is usually mounted on a special 1 ft 4½ in. rack located at a suitable point in the exchange. This rack works in conjunction with a number of access racks which contain the uniselectors or 2-motion selectors necessary for obtaining access to the equipment under test. There is usually a considerable number of wires between the access selectors and the selectors to be tested, and hence, in order to minimize the cabling costs, the access racks are placed as close as possible to the selector, etc., racks. In some cases, the access selectors are mounted on the normal apparatus racks. In the larger exchanges (especially where the same type of equipment is located on two floors) a duplicate control and display panel is provided to facilitate the supervision of routine testing.

Fig. 742 shows the general outline of a typical automatic routiner. The equipment can be considered as comprising:

(*a*) A test unit.
(*b*) An access control unit.
(*c*) Access selectors.

In the example given, the access selectors are of the 100-outlet 2-motion type, but in other circumstances the access circuit may consist of primary and secondary access switches of the uniselector type.

The testing elements are connected to the banks of a test switch, and the wipers ($T2$) of this switch are extended via the access selectors to the incoming wires of the selector under test. A certain selector bank contact number (or numbers)—usually the last outlets on the 9th level—are set aside for test purposes. These numbers are multipled throughout all selectors, and are wired to further wipers ($T3$) of the test switch. The bank contacts of the latter are connected to suitable elements to test the called side of the selector circuit and to provide the necessary co-ordination with the tests applied from the incoming wires. The test unit is arranged so that, if a selector passes a test successfully, the test switch wipers are moved to the next test position. The test switch driving magnets are associated with a time delay circuit so that, if the test switch does not proceed from one test to another within a predetermined period, fault conditions are assumed to exist and a suitable alarm is given. If the selector responds satisfactorily to all the tests, a signal is sent to the access control unit, and this circuit now causes the access selector to make one step to seize the next selector for test. The process continues automatically throughout all the selectors in the exchange until a fault condition is encountered

or the routine cycle is completed. In either case an alarm is given to attract the attention of the maintenance staff.

A series of lamps is provided in order to indicate the access selector in use at any particular time and also the contacts on which the wipers of the access selector are standing. A lamp is also provided for each position of the test switch so that the test conditions being applied at any particular time can be observed. If the test switch fails to step due to fault conditions, then the sequence of tests whilst examining the actual switch under test.

Most routiners are provided with a series of fault imitation keys, by means of which the functioning of the routiner can be checked from time to time.

Final Selector Routiner. The space available in this volume does not permit of a description of all the various types of routiners which may be used in a standard automatic exchange. The principles of design are substantially the same for routiners of all classes, and in the following paragraphs the

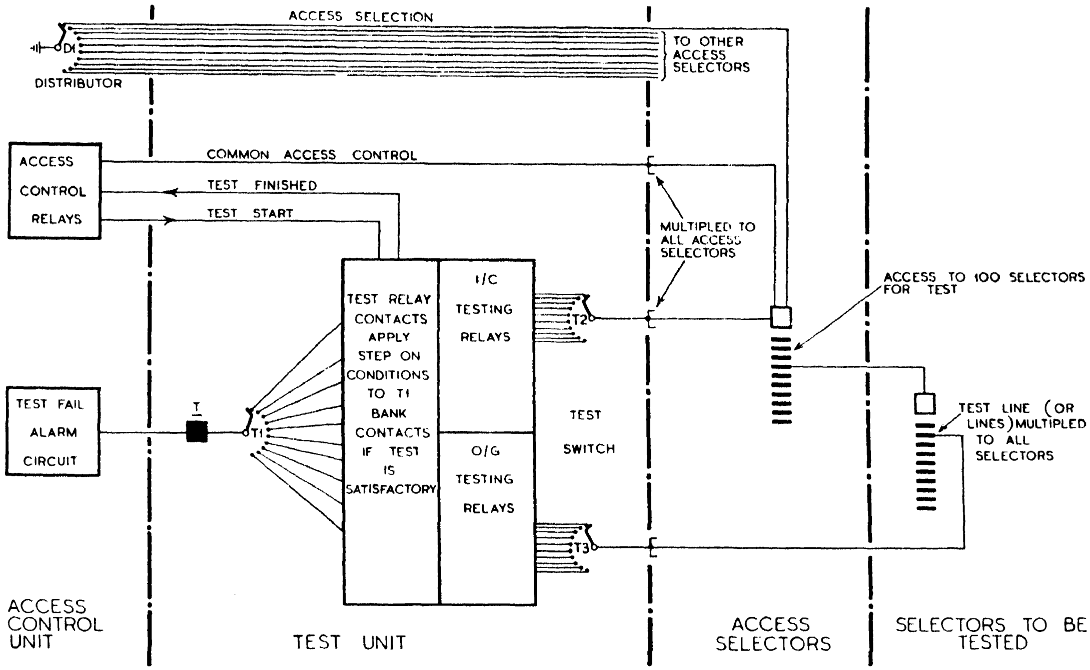


FIG. 742. OUTLINE DIAGRAM OF A TYPICAL AUTOMATIC ROUTINER

glowing of one of the test lamps indicates the nature of the fault, whilst the lamps associated with the access control circuit indicate the particular selector concerned.

A key is usually provided on the routiner so that the access selector can be stepped to any particular contact in order that a test can be carried out on a certain selector. If necessary, the routiner can be set so that one particular selector can be continuously routined (i.e. the circuit feature which causes the access switch to step to the next circuit at the end of the test is temporarily cut out). If a fault is encountered whilst a circuit is under continuous routine, it is possible to re-set the test unit so that the sequence of tests is re-applied to permit observation of the failure. A remote control of the re-set feature is provided so that the maintenance staff can repeat main features of a final selector routiner are described as illustrative of routiner design practice.

Apart from its functions of connecting the test equipment to any final selector as required, the final selector routiner provides the following functional tests:

(1) A selector busy test.

(2) A polarity and continuity test of the incoming negative line.

(3) A polarity and continuity test of the incoming positive line.

(4) A test of the earth guard on the incoming P-wire.

(5) Impulse accepting relay release test.

(6) Impulse accepting relay operate test.

(7) Test of the release guard period on the incoming P-wire.

(8) Impulsing test under short line conditions.

(9) Test for seizure of first test line.

(10) Test for earth on *P*-wire of the selector multiple.

(11) Test for receipt of ringing and non-operation of ringing trip relay.

(12) Test for tripping of ringing.

(13) Polarity and continuity test on outgoing negative line.

(14) Polarity and continuity test of outgoing positive line.

(15) Test for reversal of polarity of incoming negative and positive lines under called subscriber answer conditions.

(16) Test for absence of battery or earth on the *P*2 wiper (P.B.X. final selectors only).

(17) Test for release of the selector from the called subscriber answered condition.

(18) Short line impulsing test with the test line busied.

(19) Test for reception of busy conditions.

(20) Test for disconnexion of positive and negative wipers on a busy call.

(21) Test for release of selector under busy conditions.

(22) Impulsing test of selector under long line conditions.

(23) Test for seizure of the second test line.

In order to avoid confusion, a number of the above tests have been omitted in the following circuit elements (in particular, the facilities associated with the testing of P.B.X. final selectors).

Access Control Circuit. Fig. 743 shows the more important parts of the access control unit, and the connexions to the access selector. The movements of the access selector are controlled over a common multiple which serves all access selectors in the exchange. The particular access switch to be taken into use at any given time is determined by the position of the access control unit distributor (*D*). Provision is made for the access selector wipers to step over unequipped bank positions (i.e. those to which no final selectors are connected) by the use of two connexion fields. The cross-connexions shown in Fig. 743 assume that:

(*a*) The first two distributor positions (contacts Nos. 2 and 3) have no access selectors.

(*b*) Levels 5 and 7 only are equipped on the 1st access selector of the series.

(*c*) Positions 6, 7, and 8 only are equipped on the 5th level of the 1st access selector.

When the routiner start key (*KS*) is thrown, the closure of contacts ***KS*1** extends an earth (from *H*2) over the *AM*-lead of the 1st access selector. (It will be noted that the *AM*-lead is connected as a series circuit through all the access selectors.) The earth from ***KS*1** is applied via the cross-connexion field, and thence to operate one or more of the level marking relays (*MA*, *MB*, *MC*, and *MD*). In the example shown, the 5th level of the access selector is the first equipped level, so that the earth is extended to operate relays *MB* and *MD*.

Relay *H* now operates from the home contact of the *D*2 arc and locks via ***H*2**. ***H*8** provides a holding circuit for the level marking relays (i.e. for *MB* and *MD* in this case). The distributor (*D*) is stepped from normal by the operation of contact ***H*6**, and then drives under self-interrupted action over the unequipped positions as determined by the distributor cross-connexion field.

The slow-to-release relay (*PD*) is included in this drive circuit and is operated during stepping to prevent (at ***PD*1**) the closure of the access selector vertical drive circuit. When the first equipped position is reached (contact 4 in Fig. 743) the drive circuit of the distributor is broken, and the earth from ***KS*2** is extended via the *D*3 wiper to operate the *B* relay in the 1st access selector. *B* locks to its own contact ***B*7** under the control of the earth from ***H*4** via the busy hold lead (*BH*). After a period of lag, relay *PD* releases at the end of distributor drive, and at *PD*1 completes the vertical magnet circuit of the access selector. The *V* magnet is energized over this circuit and, when the vertical make springs (***V*1**) close, earth from ***B*1** is returned to operate relay *TF*. ***TF*5** now completes a circuit for relay *PD* which operates, and at ***PD*1** disconnects the vertical magnet circuit. This interaction of the vertical magnet, the *TF* relay and the *PD* relay continues until the first equipped level (e.g. 5) is reached.

A preliminary test start signal (earth) is now returned to the test unit over the *DA*-lead via one section of the vertical marking bank (*AW*). Relay *EQ* operates from the earth on the *BH*-lead via the second section of the vertical marking bank, contacts ***MB*2** and ***MD*3**, and thence via one coil of the *TF* relay. *TF* holds over this circuit to arrest the access selector vertical drive, whilst *EQ* operates and locks at ***EQ*4**. ***EQ*3** cuts the vertical stepping circuit of the access selector in readiness for the release of *PD*1. ***EQ*5** short-circuits the holding coil of relay *TF* and, after a period of lag, *TF*5 disconnects the circuit of *PD*.

During the release lag of *TF*, an earth is extended from ***TF*1** via ***EQ*1**, the *RM*-lead, and the ***B*4** contact of the access selector to energize the rotary magnet. In due course *TF*1 releases and disconnects the *R* magnet circuit. If the first rotary position is unequipped, earth is extended from contact ***B*1** via arc 4 of the selector,

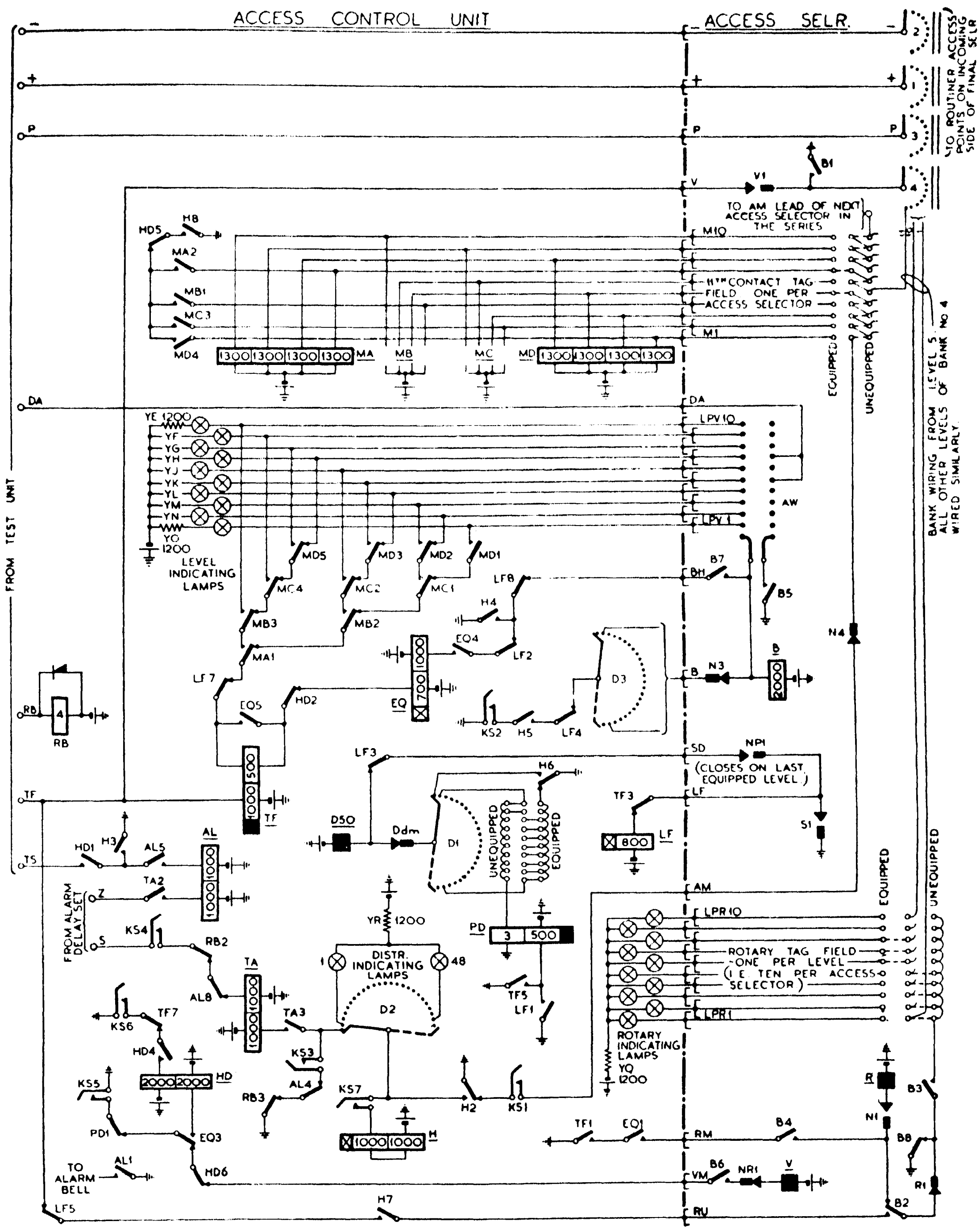


Fig. 743. General Circuit Arrangements of Access Control Unit (Final Selector Routiner)

the rotary cross-connexion field, **B3**, *R*1, **B2** and thence to the *RU*- lead to operate relay *TF*. ***TF*1** again energizes the rotary magnet, and this process continues until the wipers reach the first equipped position on the selected level (e.g. contact No. 6). There is now no circuit for the *TF* relay due to the different strapping on the rotary connexion field. The —, +, and *P*-wires from the test unit are now connected to the incoming wires of the first final selector in the series. Earth from ***B*1** is extended via the rotary connexion field to light the appropriate rotary indicating lamp in the access control unit.

Relay *PD* releases at the conclusion of rotary stepping. (*PD* is, of course, held during rotary stepping due to the repeated application of earth at the ***TF*5** contact.) The restoration of *PD*1 allows relay *HD* to operate and lock via ***HD*4**. A test start earth signal is now given to the test unit from contact ***H*3** via ***HD*1** and the *TS*-lead. The level marking relays are now released at ***HD*5**.

The test uniselectors obtain their battery supply via relay *RB* in the access control circuit. Relay *RB* is therefore operated for a short period when the test selector is energized after the completion of a test. Relay *TA* (access control circuit) is connected via ***KS*4** to the *S*-lead of an alarm delay relay set. *TA* operates to the first *S* pulse and holds via ***TA*3** and ***KS*3** to the earth at *RB*3. ***TA*2** extends one coil of the *AL* relay to the *Z*-lead. If the tests are proceeding satisfactorily, relay *RB* operates in the interval between the *S* and *Z* pulses, and at ***RB*3** releases relay *TA*. If, however, a fault is encountered, the test switch fails to step and the failure of the *RB* relay to operate maintains the *TA* relay. In due course the *Z* pulse is applied and operates relay *AL* to give audible alarm conditions.

If no faults are found, the test switch continues to step until the complete cycle of tests has been completed. A momentary earth signal is now passed over the *TF*-lead to the access control circuit. Relay *TF* operates to this signal and at ***TF*5** energizes *PD*. ***TF*7** and ***PD*1** release relay *HD*, and *HD*1 in turn withdraws the test start earth signal from the *TS*-lead. The *R* magnet is energized over the *RM*-lead from the earth at ***TF*1**. Relay *TF* releases at the end of the momentary signal from the test unit and disconnects the *R* magnet at contact *TF*1. *TF*5 releases relay *PD*, and the restoration of *PD*1 allows *HD* to re-operate and lock via ***HD*4** and *TF*7. The test start signal is now re-applied to the *TS*-wire by ***HD*1**. By this means the access selector is stepped over the

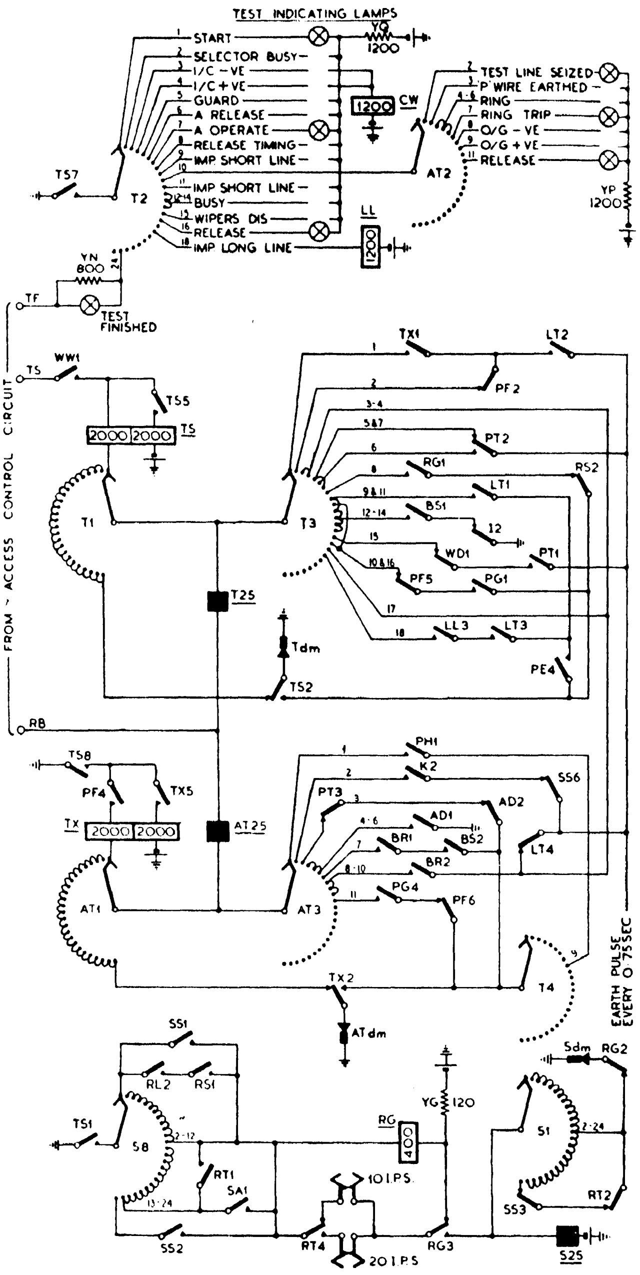
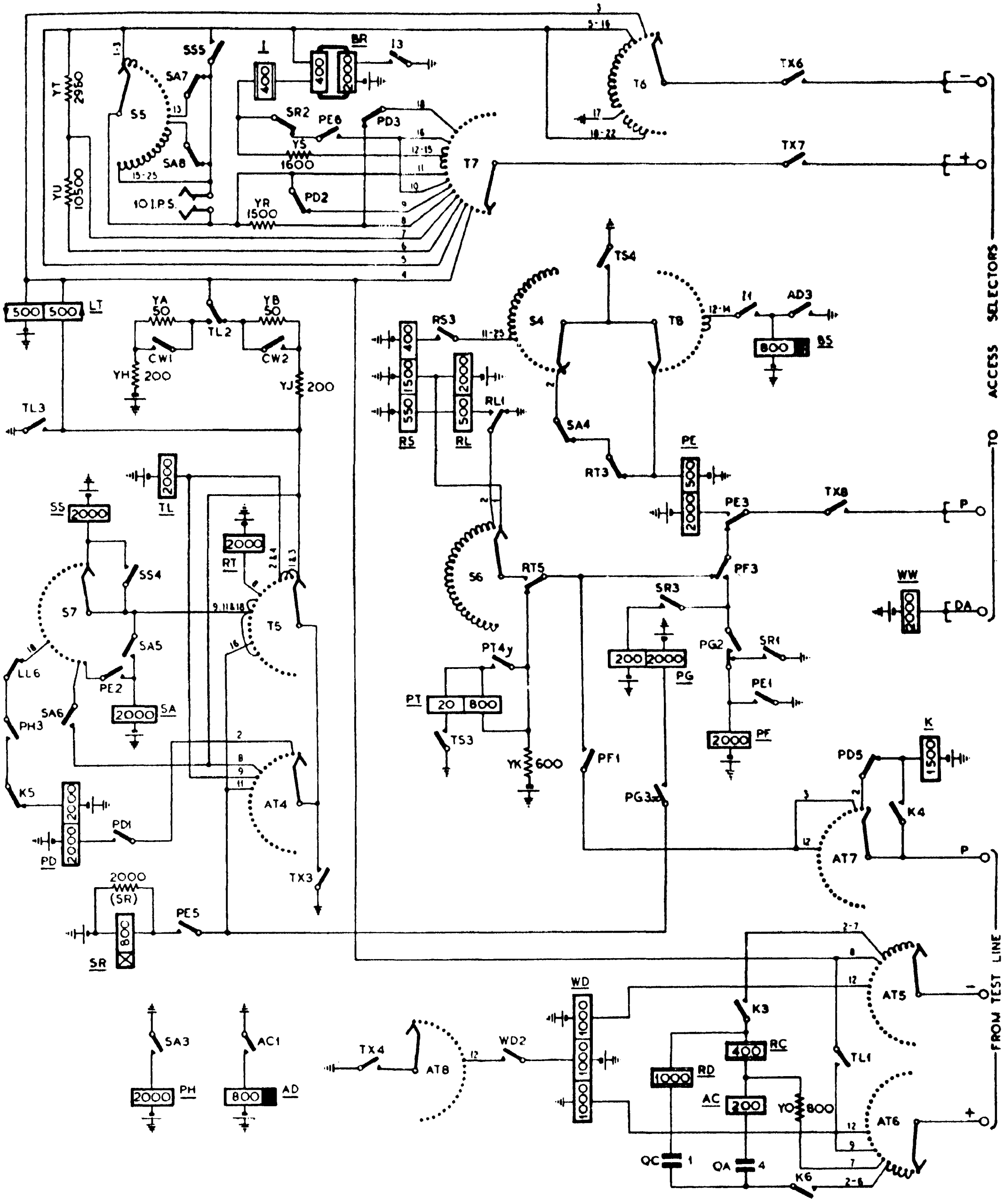


FIG. 744. MAIN ELEMENTS OF TEST UNIT

consecutive rotary positions to test all the final selectors connected to that level.

When the "test finished" signal is received for the last final selector on the level, the access

selector wipers are stepped to the 11th rotary position. The earth from *B*1 is now extended via *S*1 springs also operates relay *LF*, and *LF*1 holds the *PD* relay before it releases from the final



(FINAL SELECTOR ROUTINER)

bank No. 4 to the vertical cross-connexion field to operate the marking relay combination for the next equipped level. If, as in Fig. 743, this is level 7, relay *MA* is operated. The closure of the rotary step. *LF*2 disconnects the holding circuit for relay *EQ*, whilst *LF*8 removes the earth from the *BH*-lead to release the *B* relay. Relay *HD* also releases due to the restoration of *EQ*3, and

*HD*5 restores the holding circuit for the level marking relays so that relay *MA* locks via ***MA*2** to the earth at ***H*8**. The access selector now restores in the normal manner, i.e. it self-drives to the 12th rotary position by means of the earth at *B*8, and then restores mechanically. Relay *LF* releases when the *S*1 springs open and, when the selector reaches its normal position, the reclosure of the *N*3 springs allows relay *B* to re-operate to the earth from the distributor uniselector and lock via the *BH*-lead as before. The restoration of *LF*1 releases *PD*, and *PD*1 gives an initial impulse to the vertical magnet. The vertical stepping cycle now takes place again until the wipers reach the marked level (now level 7). The final selectors on each equipped contact of this level are tested in the manner already described, and the process continues until the wipers reach the 10th contact of the last equipped level. At this point the "test finished" signal causes the access selector to move to the 11th contacts, and the ***B*1** earth is extended via bank No. 4 and the vertical connexion field to the *AM*-lead of the next access selector. This earth is applied to the vertical connexion field of the 2nd access selector to mark the first equipped level of that selector.

The normal post springs (***NP*1**) of the 1st access selector close on the last equipped level. When all selectors have been tested, the closure of the *S*1 contacts applies earth to the *SD*-lead to energize the distributor driving magnet when contact *LF*3 restores. The distributor steps to the 2nd access selector to operate the *B* relay, and the process continues in this manner until all final selectors have been tested.

When the last access selector steps to the end of its last equipped level, the ***B*1** earth signal (which is used during the routine for level marking) is extended over an *RF*-lead (not shown in Fig. 743). This is the "routine finished" signal and causes relay *AL* to operate. On receipt of this alarm, the engineer in attendance releases the start key (*KS*) and the routiner restores to normal.

Test Unit Circuit. Fig. 744 shows the main testing elements of a final selector routiner. The order of the tests is indicated by the designation of the "test indicating" lamps. One of these lamps glows for each position of the test switch (and auxiliary test switch).

When the access equipment has connected a final selector to the test unit, test start earth signals are transmitted (as described in the previous section) over the *DA*- and *TS*-leads. Relay *WW* operates to the earth signals on the *DA*-lead, and ***WW*1** energizes relay *TS* from battery via the test switch driving magnet to the earth on the *TS*-lead. The *TS* relay locks independent of the test switch at ***TS*5**, this arrangement ensuring that a test cycle cannot be started unless the test switch is on its home contact.

The closure of contacts ***TS*3** operates relay *PT* which holds on its low resistance winding. ***TS*4** operates relay *PE* via the home contact of the *T*8 arc. ***PE*1** in turn operates relay *PF*, whilst ***PF*4** completes a circuit for relay *TX* via the home contact of the first arc of the auxiliary test switch (*AT*1). The *TX* relay locks at ***TX*5** under the control of ***TS*8**.

The operation of relay *TX* completes a circuit for relay *LT* at ***TX*3**. *LT* is differentially wound but operates under the present conditions due to the unequal current in its two windings resulting from the shunting effect of resistors *YB* and *YJ*. The initial operating conditions of *LT* are shown diagrammatically in Fig. 745A. A circuit is now completed from the "0·75 sec earth pulse" via ***LT*2**, ***TX*1**, and the home contact of the *T*3 arc to the battery at the test switch driving magnet. The first earth pulse energizes *T* and the removal of this earth condition at the end of the pulse allows the test switch to move its wipers to the second position.

Selector Busy Test. The second contacts of the test switch are associated with the selector busy test circuit. Relay *TL* operates from the earth at ***TX*3** when the *T*5 wiper moves to the second position. ***TL*3** holds the *LT* relay. If the final selector under test is engaged, relay *PE* holds (via ***PE*3** and ***TX*8**) to the earth on the incoming *P*-wire of the selector. This arrests the action of the routiner, and if the condition persists for the alarm delay period of the access control circuit, audible alarm conditions are set up. (The alarm condition is produced as described previously if there is a prolonged interval between consecutive energizations of the test switch magnet.)

If the final selector is free, relay *PE* releases due to the absence of a holding circuit on the *P*-wire (the initial operating circuit being broken at the *T*8 arc). *PE*1 releases *PF* and the 20 Ω coil of relay *PT* is now extended to the *P*-wire (via *PF*3 and *PE*3) in order to guard against seizure by ordinary traffic whilst the selector is undergoing routine tests. *PF*2 now extends the test switch driving magnet to the earth pulse supply and at the end of the next pulse the test switch moves to the third contacts.

Incoming Negative Line Test. The third contacts of the test switch are reserved for a test of the incoming − line of the selector. With the test switch in this position the holding circuit of relay *TL* is broken at the *T*5 wiper, but, on the release

of *TL*3, the earth in the *LT* relay circuit is maintained from **TX3** via the *T*5 wiper and bank. Relay *CW* operates in series with the test indicating lamp from the earth at the *T*2 wiper. **CW2** now prepares the testing bridge.

The incoming — line of the final selector is at this stage connected via the *T*6 wiper to the line test relay (*LT*). The connexions are as shown in Fig. 745B. The two windings of the *LT* relay form one pair of arms of a bridge, whilst one coil of the final selector *A* relay and the 200 Ω resistor *YJ* form the second pair of arms. If the resistance of the — line (i.e. to the battery behind the *A* relay) is correct, the current is the same through both windings of the *LT* relay. Under these conditions relay *LT* releases due to the differential connexions of its windings and the 0·75 sec earth pulse, operating via contact *LT*4, causes the test switch to step to the 4th set of bank contacts.

If there is a disconnexion, high resistance, short circuit or earth fault on the — wire, *LT* fails to release and the absence of the step-on condition brings in the routiner alarm circuit.

Incoming Positive Line Test. Relay *TL* operates to the **TX3** earth when the *T*5 wiper moves to the 4th position. The incoming + line of the final selector is now connected via the *T*7 wiper to the *LT* relay circuit. The conditions are now as shown in Fig. 745C. As before, the bridge is balanced if the resistance of the + line is equal to that of resistor *YH*. Under correct conditions, the *LT* relay therefore releases and re-establishes the test switch stepping circuit at *LT*4, thereby causing the wipers to move to the 5th position. Any disconnexion, earth fault or other irregular condition on the + wire unbalances the bridge so that the currents in the two windings of *LT* are unequal, and the relay holds. Alarm conditions are established after the usual delay period.

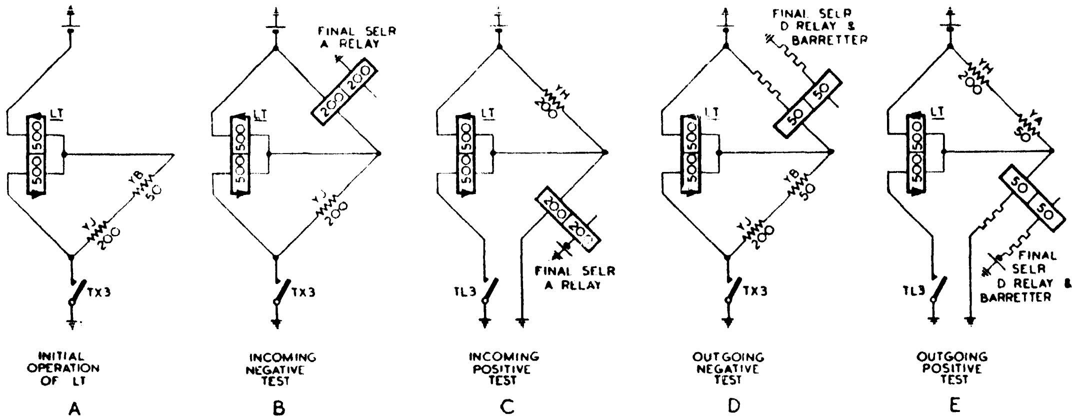


FIG. 745. CONNEXIONS OF LINE-TEST RELAY

Guard Test. With the test switch stepped to the 5th position, relay *TL* is released at the *T*5 arc, and relay *CW* is released at the *T*2 arc. The incoming — and + lines of the final selector are now looped via the *T*6 and *T*7 arcs. This loop operates the final selector *A* relay, which in turn completes the circuit for the holding and guarding relay (usually *B*). Under correct conditions a contact of the *B* relay should now return earth on the *P*-wire to hold the switching train and to guard the final selector against intrusion. The return of this earth on the *P*-wire shunts out the holding battery (at *YK*) of the *PT* relay, which releases and at *PT*2 completes the test switch stepping circuit. Failure of the *PT* relay to release indicates a fault on the guarding circuit and prevents the stepping of the test switch, alarm conditions being given after the usual delay period.

A-relay Release Test. When the test switch wipers move to the 6th position, resistors *YU* and *YT* are connected in series with the holding loop across the — and + wires. The value of these resistors is so chosen that the *A* relay should now release. If the adjustments of the *A* relay are satisfactory, the release of this relay is indicated by the removal of the guarding earth on the *P*-wire, which in turn allows relay *PT* to re-operate. The changeover of contact **PT2** applies the step-on condition to the test switch magnet. As before, a fault condition is indicated if the *PT* relay fails to release within the alarm delay period of the access control circuit.

A-relay Operate Test. The 7th contact of the test switch applies an operate test to the final selector *A* relay by including resistor *YT* (2950 Ω) in series with the loop across the — and + lines.

If the A relay operates under these conditions, earth is returned on the P-wire to release relay PT as already described for earlier tests. The release of $PT2$ now completes the test switch step-on circuit to move the wipers to the 8th position. (It will be noted that the A-relay operate test is applied subsequent to the guard test so that the A-relay contacts, the B relay, and the B-relay contacts in the P-wire circuit are already proved correct before the application of the A-relay operate test.)

Release Timing Test. When the test switch wipers are stepped to the 8th rotary position, the + and − lines of the final selector are looped via resistor YR (1500 Ω) and the home contact of the $S5$ arc. Relay RT is now operated from the earth at ***TX*3** applied by the $T5$ wiper. ***RT*5** now extends the P-wire earth via the $S6$ wiper to operate relays RL and RS. ***RT*4** applies the 20 I.P.S. magnet springs to the RG relay circuit and, at the first break of the impulse springs, RG operates from the ***TS*1** earth via $S8$, ***RL*2**, ***RS*1** to the battery at resistor YG. This circuit element has already been seen in a number of earlier circuits (e.g. the director), and is designed to prevent the delivery of a clipped initial impulse to the send switch driving magnet. The operation of ***RG*3** connects the impulse springs to the send switch driving magnet (S) and the send switch now drives at 20 steps per second, i.e. each consecutive step of the S wipers indicates a timing period of 50 msec. When the S switch reaches the 4th position, the holding loop to the final selector is disconnected at the $S5$ wiper. If, now, the final selector does not withdraw the P-wire guarding earth (as it should) within 350 msec, i.e. before the S switch reaches the 11th contacts, the RS relay holds on its 400 Ω winding to the earth at the $S4$ wiper. The S switch drives to its 25th position and, since ***RS*2** remains operated, the test switch cannot move to the next test, and alarm conditions are set up.

If the final selector functions correctly, relay RS releases due to the withdrawal of the P-wire earth by the final selector before the S switch can hold the RS relay from the $S4$ arc. Relay RL also releases due to the removal of the earth from the P-wire, and $RL1$ guards the final selector from normal traffic until $RT5$ restores. The test switch now self-drives to the 9th position (via ***RG*1**, $RS2$, and ***TS*2**). The holding circuit for relay RT is now broken at the $T5$ arc, and the release of $RT1$ disconnects RG. (The $S8$ wiper has passed beyond contact No. 12 at this stage.) On the release of RG, the S switch self-drives to its home position from the earth on the $S1$ bank.

Short Line Impulsing Test. With the test switch in the 9th position, a holding loop of zero resistance is applied to the final selector via the $T6$ arc, the $S5$ arc, and the $T7$ arc. Relay SS now operates to the earth extended by the $T5$ wiper and the home contact of the $S7$ bank. ***SS*4** provides a locking circuit independent of the S switch. The closure of contact ***SS*1** allows relay RG to operate on the first disconnexion of the 10 I.P.S. magnet springs, and ***RG*3** extends the impulse springs to the S magnet. The S switch steps over this circuit and 9 impulses are transmitted to the final selector whilst the $S5$ wiper is passing from contact No. 4 to contact No. 13. After this point, the 10 I.P.S. line impulsing springs are short-circuited at the $S5$ arc. Thus the selector under test is raised to the 9th level under the control of standard impulses transmitted over a line of zero resistance.

During the passage of the $S4$ wiper over its second contact, a circuit is completed from the earth at ***TS*4** to operate relay PE. PE locks (at ***PE*3**) to the earth returned by the final selector over the P-wire. ***PE*1** operates relay PF, whilst ***PE*3** removes the shunting condition from the PT relay to allow the latter to operate. Similarly, when the $S8$ wiper reaches contact No. 13 the holding circuit for the RG relay is broken and the S switch homes via the earth applied to the $S1$ arc by $RG2$. When the $S8$ wiper reaches the 25th bank contact, a circuit for RG is again provided (via ***SS*2**) to prepare the circuit for the rotary stepping of the final selector. Relay SA also operates via ***PE*2** and the $S7$ bank when the send switch wipers reach the 25th position. ***SA*5** provides an independent locking circuit, whilst ***SA*7** and ***SA*8** open up further contacts on the $S5$ bank so that 11 impulses will be counted during the transmission of the next train. ***SA*3** operates relay PH, and ***PH*1** completes a drive circuit for the auxiliary test switch (AT). The latter self-drives via ***PH*1**, contact 9 of the $T4$ arc, and ***TX*2** so that the wipers are stepped to the 2nd position in readiness to carry out the "test line seized" test.

The S switch continues to drive at 10 I.P.S., and 11 rotary impulses are given to the final selector whilst the $S5$ wiper passes from contact No. 4 to contact No. 15. At this point the line impulsing springs are again short-circuited at the $S5$ arc. The final selector under test is thus rotated to the 11th contact on level 9, i.e. the contact set aside as a test line for routine purposes. Relay LT operates via ***SA*6**, the 24th contact of the $S7$ arc, the $T5$ bank and wiper to the earth at ***TX*3**. The relay releases when the $S7$ wiper passes forward from the 24th to the 25th contact. This

momentary operation of the *LT* relay causes the test switch to self-drive via ***LT*1**, ***PE*4**, and ***TS*2** to step the wipers to the 10th position.

The test switch remains in the 10th position until certain tests are carried out by the auxiliary test switch. When the wipers move to the 10th position, relays *SA* and *SS* are both released by the withdrawal of the earth at the *T*5 wiper. *SS*1 and *SS*2 in turn release the *RG* relay, and the *S* switch drives via the *S*1 arc to its home position. *SA*3 also releases the *PH* relay. The final selector under test is now positioned on the 11th rotary contacts of level 9 which are wired back to the test line circuit of the routiner. Relays *WW*, *TS*, *TX*, *PT*, *PE*, and *PF* in the test unit are operated, *PE* being held to the *P*-wire earth returned by the final selector.

The auxiliary test switch is now standing on its 2nd contacts.

Test Line Seized Test. If the final selector is functioning satisfactorily, it should seize the test line within a period of 300 msec from receipt of the last rotary impulse. If these conditions obtain, relay *K* operates to the earth applied to the forward *P*-wire from the final selector. (The battery-connected *K* relay provides the required switching condition for the final selector.) After operation, relay *K* locks via ***K*4** to the earth on the *P*-wire. The 0·75 sec earth is now applied via ***K*2** to step the auxiliary test switch to the 3rd position.

If the *K* relay does not operate within the prescribed time limit, relay *PD* operates via *K*5 when the *S*7 wiper is passing contact No. 18. ***PD*1** provides an independent locking circuit to the earth at the *AT*4 arc. ***PD*5** prevents subsequent (late) operation of relay *K*. Under these conditions *K*2 cannot complete the stepping circuit of the auxiliary test switch, the routine stops, and an alarm is given.

Outgoing P-wire Earthed Test. The 3rd position of the auxiliary test switch provides a test for earth on the outgoing *P*-wire. If the final selector functions correctly, it applies full earth forward to the test line over the *P*-wire. This earth, applied via *AT*7 and *PF*1, shunts out the holding battery of relay *PT* so that the latter releases. *PT*3 completes a step-on circuit for the auxiliary test switch.

Ringing Test. The stepping of the auxiliary test switch wipers to the 4th rotary position allows relay *PT* to re-operate due to the removal of the shunting earth at the *AT*7 arc. Relay *AC* now operates to the ringing current applied to the — and + lines of the test number. ***AC*1** energizes the slugged relay (*AD*) whilst ***AD*3** operates relay *BS*. The auxiliary test switch now steps to contact 5 due to the completion of the stepping circuit at ***AD*1**. Two more periods of ringing current are checked in the same way, relay *AD* operating once during each period. The wipers of the auxiliary test switch are thus stepped to the 7th position.

Ring-trip and Supervisory Test. With the auxiliary test switch wipers at contact No. 7, a d.c. loop consisting of resistor *YO* (800 Ω) and inductor *RC* is provided across the — and + lines. This represents the Called Subscriber Answered condition. It will be recalled that the operation of the ring-trip relay in a final selector extends the called subscriber supervisory relay to the forward loop, and the operation of this relay reverses the current in the incoming loop to the final selector (see Chapter XI). If this reversal is satisfactorily received, the shunt-field relay (*BR*) operates to the line current reversal and at ***BR*1** allows the auxiliary test switch to step to the 8th position.

Outgoing Negative Line Test. With the auxiliary test switch in the 8th position, the line testing relay (*LT*) (with its associated bridge circuit) is connected via the *AT*5 arc to the outgoing — line of the final selector. The theoretical circuit arrangements of the testing bridge are shown in Fig. 745D. In this case resistors *YJ* and *YB* provide a 250 Ω arm to balance one 50 Ω coil of the final selector *D* relay plus one filament of the ballast resistor. If the resistance of the — line is correct, *LT* does not operate and the 0·75 sec earth pulse is applied via *LT*4 and ***BR*2** to step the auxiliary test switch.

Outgoing Positive Line Test. The stepping of the auxiliary test switch to the 9th contacts allows relay *TL* to operate via the *AT*4 bank and wiper. The line testing bridge is now connected via ***TL*1** and the *AT*6 wiper to the outgoing + line of the final selector. The theoretical conditions are shown in Fig. 745E. If the + line is of the correct resistance, *LT* does not operate and the earth pulse applied via *LT*4 and ***BR*2** steps the auxiliary test switch to the 10th position. Relay *TL* now releases due to the removal of the earth at the *AT*4 wiper.

Contacts No. 10 of the auxiliary test switch are utilized in the complete final selector routiner for the testing of 200-line selectors. In the limited circuit of Fig. 744 this test position is not used, and the auxiliary test switch is again stepped via *BR*2 so that the wipers move to the 11th set of contacts.

Release Test. We have seen in earlier chapters of this volume that, when the holding loop is

withdrawn from a final selector of the 2000 type, the following release sequence takes place:

(*a*) Relay *A* releases.

(*b*) Relay *B* releases to withdraw the earth from the incoming *P*-wire.

(*c*) Relay *C* releases to provide a guarded release feature by earthing the *P*-wire until the off-normal contacts restore.

The final selector routiner provides a test to ensure that the unguarded period (i.e. the period between the release of *B* and the release of *C*) is not excessive.

Earth extended via the 11th contact of the *AT*4 arc operates relay *SR*, and ***SR*2** in turn disconnects the holding loop to the final selector. Relay *BR* releases due to the cessation of line current, and in due course relay *K* is released by the removal of the earth from the *P*-wire of the test number. Relay *PE* (which up to now has been holding from the earth on the *P*-wire) releases during the unguarded period and *PE*3 extends the *P*-wire towards the *PF* relay. (The *PF* relay, however, holds at the present time under the control of the slow relay *SR*.) When the *C* relay in the final selector restores, the earth is re-applied to the incoming *P*-wire, and relay *PG* operates via ***SR*3** and ***PF*3**. ***PG*3** provides an independent locking circuit under the control of the *AT*4 wiper. ***PG*2** provides a similar locking circuit for the *PF* relay under the control of the earth on the *P*-wire. The release lag of the *SR* relay exceeds the length of a normal unguarded period so that, if conditions are correct, the *SR* relay does not release after the re-application of earth to the *P*-wire by the final selector.

When the selector restores to normal, the restoration of the off-normal springs withdraws the earth from the *P*-wire to release relay *PF*. *PF*3 extends the *P*-wire to the low resistance earth via the 20 Ω coil of the *PT* relay to guard the selector against seizure by normal traffic. The main test switch (*T*) now self-drives via *PF*5 and ***PG*1** until the wipers reach contacts No. 11. Similarly, the auxiliary test switch self-drives via ***PG*4** and *PF*6 to the 12th rotary position. The auxiliary test switch now rests in this position whilst certain other tests are carried out by the main test switch. The holding circuit for relay *PG* is broken at the *AT*4 wiper, and the relay releases.

If relay *SR* releases before the end of the unguarded period (i.e. if this period is too long), then *PG* cannot operate (via *SR*3) at the end of the unguarded time. Since *PG*1 and *PG*4 remain normal in this case, neither the main test switch nor the auxiliary test switch can step, and the routine stops.

Short Line Impulsing Test. The movement of the main test switch wipers to contact No. 11 provides for the stepping of the selector in readiness for a subsequent busy test. Opportunity is taken of this operation to carry out a further short line impulsing test on the selector. The final selector is now stepped to the 11th rotary position on level 9 as described previously, and the momentary operation of the *LT* relay allows the test switch to move to position No. 12.

Busy Test. When the final selector is stepped to the test line, relays *WW*, *TS*, *TX*, *PT*, *PE*, and *PF* are operated as on the previous occasion. In addition, relay *I* now operates in series with resistor *YS* to the holding loop applied to the selector. ***I*1** in turn operates *BS*.

The test line is busied for this test by the application of a low resistance earth via the 20 Ω coil of relay *PT*, ***PF*1**, and the *AT*7 wiper. If the final selector is functioning correctly, it should now return busy flash on the incoming + line. Receipt of this flash signal is detected by the release of relay *I*, which in turn releases *BS*. Satisfactory receipt of this signal causes the test switch to drive to contact 13 due to the momentary application of earth by ***BS*1** and *I*2 during the release lag of relay *BS*.

Two more periods of busy flash are checked in the same way, thereby stepping the test switch wipers to contacts No. 15.

Wipers Disconnected Test. During the busy test the *WD* relay is applied to the − and + wires of the test line via the 12th contacts of the *AT*5 and *AT*6 arcs. If the final selector wipers are disconnected (as they should be under busy conditions) there is no circuit for the operation of the *WD* relay on either coil. The presence of ringing return battery on the + line or the earth behind the ringing supply on the − line would, however, cause *WD* to operate and prevent further stepping of the test switch. If, on the other hand, the test is satisfactory, the earth pulse is applied via ***PT*1** and *WD*1 to step the test switch to position 16.

Release Test. A further release test is now applied during the restoration of the selector in readiness for further impulsing tests. Relay *SR* operates from the 16th bank contacts of the *T*5 arc, and the release check routine is repeated in exactly the same manner as already described. After the release test, the test switch self-drives to the 17th contacts. This position is utilized for certain tests on 200-line final selectors, but the associated elements are not shown in Fig. 744. Relay *I* now releases when the *T*7 wipers move to contact No. 17, and *I*1 in turn releases *BS*.

The test switch is driven by the earth pulse (via $LT4$) to step the wipers to the 18th position.

Long Line Impulsing Test. Relay SS now operates to the earth at the $T5$ wiper, and the final selector is again stepped to the 11th rotary position on level 9. On this occasion, however, a 1500 Ω resistor (YR) is placed in series with the impulsing springs to assimilate long line conditions.

If the selector passes through this test successfully, the test switch and the auxiliary test switch are stepped over the remaining contacts (which are concerned with tests on 200-line final selectors) until they reach their home positions. As the test switch passes the 24th contacts it gives a "test finished" signal (earth from $TS7$ via the $T2$ arc and the "test finished" lamp) to the access control unit. The access equipment, on receiving this signal, connects the next final selector to the test unit.

Artificial Traffic Equipment. It is the general policy in the British Post Office to ensure satisfactory operation of automatic switching equipment by the systematic testing of individual links in the chain of connexions by routiners or testers. An overall check of the service given to the subscriber is obtained by the use of observation equipment, by means of which it is possible to watch the service on a limited number of observed calls. An "Artificial Traffic Equipment" has recently been tried out experimentally at several centres to augment the normal routiners and observation equipment.

The principle of the Artificial Traffic Equipment is illustrated in Fig. 746. Twenty-four spare subscribers' calling equipments, distributed as evenly as possible over the exchange equipment, are connected to the banks of an access uniselector A. Twenty-five spare final selector numbers (which are also spread out as far as possible over the final selector multiples of the exchange) are connected to the banks of a second access uniselector B. The access switches are stepped automatically in such a way that on the first cycle a call is passed from the first calling equipment to the first final selector number, and on the second cycle from the second calling equipment to the second final selector number, and so on, until a call is passed from the 24th calling equipment to the 24th final

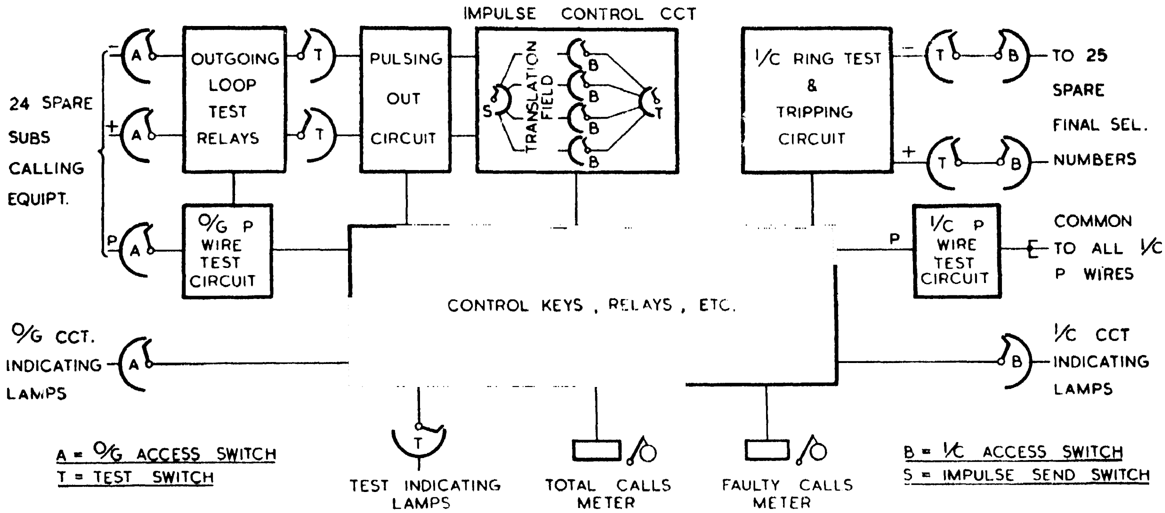


FIG. 746. BLOCK SCHEMATIC OF ARTIFICIAL TRAFFIC EQUIPMENT

selector number. The 25th outlet of the outgoing access uniselector (A) is left spare and this switch drives automatically to its first outlet after the termination of the 24th call. Hence the 25th call is from the first calling equipment to the 25th final selector number. By this means, calls are set up from each calling equipment to every final selector number connected to the equipment. Thus, for a complete run of the Artificial Traffic Equipment (A.T.E.) a total of 600 different calls are passed through the automatic equipment.

The following tests are automatically carried out during the setting up of the artificial calls:

(*a*) Continuity tests of the outgoing loop.
(*b*) Continuity test of the outgoing P-wire.
(*c*) A check of the receipt of ringing current.
(*d*) A check of the receipt of the D relay reversal conditions from the final selector.
(*e*) A check for no release conditions.
(*f*) A check for premature release conditions.

(*g*) A check of the final selector *P*-wire to indicate that one of the selected numbers has been reached.

The artificial traffic equipment is designed on the same general principles as normal routiners. Apart from the two access switches (*A* and *B*) there is a test switch (*T*) which sets up the appropriate conditions stage by stage during the establishment of a test call. The impulse control circuit is provided with a translation field so that the correct impulse trains can be applied to the outgoing circuit in order to set up a call to each of the test final selector numbers. Indicating lamps are provided to show the number of the outgoing and incoming circuits in use at any particular time, to show the progress of the call and to give a visual indication of faults (such as ring failure, premature release, *P*-wire disconnected, etc.).

The equipment is provided primarily so that maintenance officers can investigate and rectify any faulty condition encountered by the A.T.E. To assist such fault location, facilities are provided for holding any established test call, for carrying out repetitive tests between the same numbers, and for speaking and monitoring calls. An interesting feature is the provision of a tone which can be applied to the speaking pair of an established connexion in order to facilitate the tracing of the call through the automatic equipment. Two meters are provided, one indicating the total number of test calls and the second the total number of faulty calls.

Normally, the A.T.E. stops and gives an alarm when a faulty condition is encountered, but by throwing an "observation" key the circuit can be made to release faulty calls and to continue its cycle of operation. The equipment is therefore very useful for carrying out "observation" runs on the equipment to obtain a measure of the service being given to subscribers. It will be noted that the A.T.E. makes no provision for testing all the links through an exchange. The outlets over which the test calls are routed are determined by pure chance, depending upon the volume and incidence of the real traffic on the exchange. It has been found that the introduction of this Artificial Traffic Equipment has enabled a material improvement to be made in the service given to the subscribers as measured by the normal observation equipment.

Traffic Recording. It has been described in Chapter II how overflow meters, congestion meters, and so on, are provided at the various switching stages of an automatic exchange in order to give a broad indication of any overload or congestion conditions. It is necessary to supplement these facilities with an occasional check of the volume and distribution of the actual traffic on the exchange. We have seen that the rate of traffic flow (in T.U.) over any given period can be defined as the average number of simultaneous calls during that period. The period selected is normally the busy hour. The instantaneous value of the traffic flow at any part of the exchange can therefore be determined by observing the number of engaged circuits. If a large number of such observations are taken at regular intervals during a period which includes the busy hour, then the average number of engaged circuits gives the average value of traffic flow during the period in question. The average holding time of the ordinary conversational selectors, etc., is of the order of 2–3 min, and accurate results can be obtained on such circuits if the observations are repeated at, say, $\frac{1}{2}$-min intervals throughout the period of test. Equipment, such as directors, coders, etc., have a much shorter holding time, and in these cases it is necessary to repeat the observations at more frequent intervals.

It is the usual practice to carry out a complete record of the volume of traffic at each switching point in an exchange once every six months. The traffic is measured over a $1\frac{1}{2}$ hour period (which includes the busy hour) on three consecutive and representative days. Until recent years the traffic records were obtained by means of manual switch counts. For such counts it is necessary to concentrate a large staff, and to divide the exchange into a number of small sections, each of such a size that two men can carry out a check of the number of engaged selectors once every 3 min. The number of selectors which is in use at each observation are recorded, and the average value is obtained by dividing the total by the number of observations.

Such manual switch counts are fairly expensive due to the large labour force required, and it is sometimes difficult to arrange for the concentration of the requisite number of staff. Apart from such practical considerations, however, manual switch counts are liable to give erroneous results if care is not taken to ensure that the successive observations are repeated at the correct time intervals. Moreover, it is desirable, in the interests of accuracy, that the observations should be repeated at more frequent intervals than 3 min, but this is not obtainable with manual counting methods without abnormal expense.

It is now the standard practice to fit automatic traffic recording equipment in all exchanges, except the very small U.A.X.s. This equipment is designed to test the *P*-wire of each circuit in a group at regular intervals, and to record on suitable

meters the number of occasions when the engaged condition is encountered. It is readily possible, with such automatic devices, to arrange for the observations to be repeated at intervals of 30 sec on the conversational equipment, or at 12 sec for the short holding time equipment, such as directors.

Principle of Automatic Traffic Recorder. Fig. 747 shows the broad principle of the automatic recorder equipment. For purposes of explanation it is assumed that it is necessary to carry out traffic measurements on a simple 4-group grading with 22 trunks and an availability of 10. It is also assumed that the circuits have a short holding time and that it is necessary to carry out observations at intervals of 10 sec.

The *P*-wires of the selectors connected to the grading are wired out to suitable connexion strips on the traffic recorder access equipment. The bank contacts of the test uniselector (*T*) are also wired out to similar connexion strips, and a jumper field is provided so that the *P*-wires can be connected to the *T*1 bank contacts in any desired order. This jumper field is, of course, necessary due to the fact that the *P*-wires appear on one connexion strip in selector order, whilst they must be connected to the *T*1 bank in the order in which they appear on the grading.

The recording equipment consists essentially of two uniselectors, i.e. the test uniselector (*T*) and the control uniselector (*CN*). The bank contacts of the test uniselector are connected to the *P*-wires of the selectors under test as already stated, whilst the contacts of the control uniselector banks are connected to a jackfield where facilities are provided to connect the control switch contacts together or to traffic analysis meters, as required.

In the simplified circuit of Fig. 747 a continuous supply of earth pulses at a frequency of 5 I.P.S. is applied to relay *DB* when the start key is operated. The operation of ***DB*1** energizes both the *T* and the *CN* magnets, whilst ***DB*2** connects the *T*1 wiper to the *CN*1 wiper. At the first release of *DB*1, the *T*1 wiper is moved on to the 2nd bank contact, whilst the *CN*1 wiper also moves to its 2nd contact. During the next operation of *DB*, ***DB*2** extends the *P*-wire of the 1st selector connected to the *T*1 bank via the *CN*1 wiper to the control switch jackfield. If a meter is now connected to the jack corresponding with contact No. 2 of the *CN*1 bank, this meter will operate if the selector connected to contact No. 2 of the *T*1 bank is engaged. The *T*1 and *CN*1 wipers move at the rate of 5 steps per sec under the control of the earth pulse supply, thereby making a complete test of the bank in a period of 5 sec. A further 5 sec is taken up whilst the wipers are moved round to the 1st contact, and the tests are repeated. With this arrangement it is clear that the *P*-wire of every selector in the grading is tested once every 10 sec.

If a record is required of the total traffic carried by the grading, all the contacts of the *CN*1 are

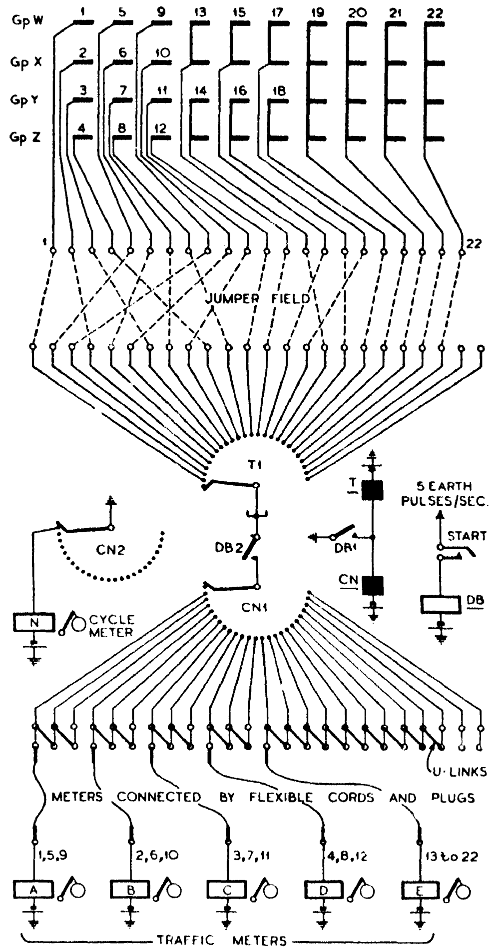


FIG. 747. PRINCIPLE OF TRAFFIC RECORDER

are connected together by inserting U-links in the appropriate jacks. One meter can then be connected to this common and will record the total number of engaged selectors encountered by the *T*1 wiper. A further meter (*N*) is arranged to record the number of cycles of test. The reading of the traffic meter, divided by the number of cycles, therefore gives the average number of selectors engaged during the period of test, i.e. it gives a direct reading of the average traffic flow (in T.U.s) during that time.

In some circumstances (especially where there is an extensive number of overflow registrations) it is necessary to measure the traffic originated from each component group of a grading. The traffic recorder provides facilities for such an analysis by the provision of additional meters and a suitable subdivision of the control switch jack-field commoning. In Fig. 747 the first 3 individual choices of group W (i.e. selectors 1, 5, and 9) are cross-connected at the jumper field to the 2nd, 3rd, and 4th contacts of the $T1$ arc. If the corresponding 2nd, 3rd, and 4th contacts of the $CN1$ bank are commoned together and connected to a traffic meter (A), this meter will record the traffic on this portion of the grading. In the same way the first 3 individual choices of group X are connected to contacts 5, 6, and 7 of the $T1$ arc, and traffic meter B is connected to record the traffic on these 3 trunks. The first 3 individual choices of groups Y and Z are similarly connected to separate traffic meters C and D. The traffic on the remaining trunks of the grading (i.e. the pairs and the full commons) is measured by a single meter E.

The total traffic carried by the grading can be obtained by adding together the readings of meters A to E and dividing the result by the number (N) of test cycles. A large part of this total traffic is carried by the first 2 or 3 trunks which are individual to the component groups. A reasonably accurate determination of the distribution of the traffic amongst the 4 groups can therefore be obtained by observing the relative volume of traffic on the first 3 contacts of the groups, and apportioning the total traffic in these ratios. Thus, with the meters connected as in Fig. 747:

Total traffic of grading (T.U.)

$$= T = \frac{A + B + C + D + E}{N}$$

Traffic carried by group W (T.U.)

$$= \frac{A}{A + B + C + D} \times T$$

Traffic carried by group X (T.U.)

$$= \frac{B}{A + B + C + D} \times T$$

Traffic carried by group Y (T.U.)

$$= \frac{C}{A + B + C + D} \times T$$

Traffic carried by group Z (T.U.)

$$= \frac{D}{A + B + C + D} \times T$$

Automatic Traffic Recorder Circuit. Fig. 748 shows the main elements of a practical traffic recorder circuit. In essence it consists of three parts:

(a) The common relay equipment, which contains various relays, start keys, etc., and which serves a number of control circuits.

(b) The control equipment with the control switch, jackfield, and the traffic analysis meters.

(c) The access selectors and their associated jumper fields for cross-connexion to the P-wires of the selectors.

In the elementary diagram of Fig. 747 the control switch is shown as controlled directly by the 5 I.P.S. pulse supply which drives the access uniselector. The arrangements are such that the control switch moves once for each step of the access switch. In the practical circuit the control switch is stepped from conditions obtained from the access selector arcs. In general it is unnecessary to provide an analysis meter for each individual trunk, and hence it is unnecessary to arrange for the control switch to make one step for each movement of the access selector. It is therefore possible to arrange the circuit so that the control switch makes one step for every two steps of the access selector or, in some cases, one step for every four steps of the access selector. The appropriate conditions are obtained by suitable strappings on the No. 7 and No. 8 arcs of the access switch, the arrangements being such that the control switch makes one half revolution for a complete test cycle.

The standard traffic recorder equipment is designed so that it is capable of recording the traffic either on conversational equipment (30 sec test intervals) or on short holding time equipment (12 sec test intervals) as desired. It is not, however, possible to carry out tests on both types of equipment concurrently. The connexions of the access selectors for the tests on conversational selectors are as shown in the upper part of Fig. 748. For such tests the access selectors are arranged in pairs (TA and TB) and each access selector is provided with 6 arcs for connexion (via the jumper field) to the P-wires of selectors. One pair of uniselectors will therefore give access to a total of 294 selectors. The circuit is arranged so that the wipers are stepped at 5 contacts per sec and, after the first switch has made a complete revolution, the stepping circuit is changed over to the second uniselector. The uniselectors are thus taken into use alternately, and the whole test cycle takes place within a 30 sec period whilst the control switch makes one half revolution. The large number of access points available makes it

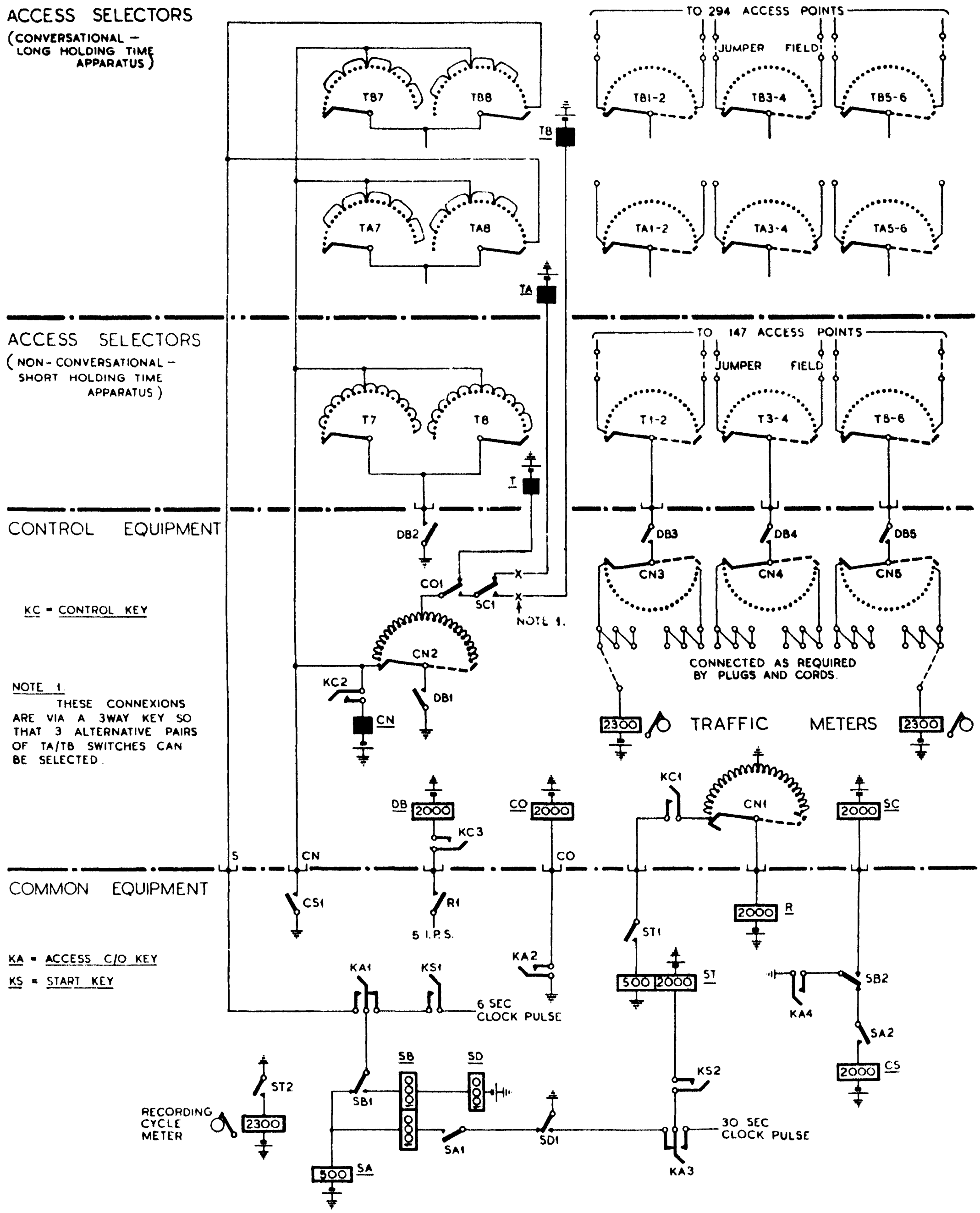


Fig. 748. Circuit Arrangements of Automatic Traffic Recorder

possible to carry out simultaneous tests on a number of separate gradings.

The access selectors for the short holding time equipment are also provided with 6 effective arcs, i.e. each uniselector gives access to 147 points. As before, the uniselector is stepped at 5 I.P.S. and makes one complete revolution within a period of 12 sec, whilst the control switch rotates one half revolution.

Tests on Short Holding Time Equipment. The recorder is started by the operation of *KS* in the common equipment and by the appropriate *KC* keys in the control equipment. Contacts ***KC*3** connect relay *DB* to a 5 I.P.S. earth pulse supply. This supply is obtained by the use of a standard impulse machine (with an impulse frequency of 10 I.P.S.) in conjunction with a pulse halving circuit. (The pulse halving circuit has been omitted from Fig. 748 in the interests of clarity.) Contacts ***KS*1** apply a 6 sec clock pulse supply via *KA*1 and *SB*1 to the *SA* relay. The arrival of the first earth pulse operates relay *SA*, and ***SA*1** prepares for the operation of relay *SB* which is, however, shunted by the clock pulse earth at this stage. At the end of the pulse period, *SB* operates in series with relay *SA* to the earth at *SD*1. The arrival of the second clock pulse now operates relay *SD* via ***SB*1**, and at the same time holds relay *SB* on its second winding. ***SD*1** now releases *SA* and also completes a circuit for the *ST* relay. The closure of contact ***ST*2** operates the recording cycle meter. ***ST*1** completes a circuit for relay *R* via the home contact of the *CN*1 arc. Contact ***R*1** starts up the 5 I.P.S. pulse supply circuit, and the first operation of ***DB*1** energizes the control switch magnet (*CN*). At the end of this pulse the control switch wipers step to the 2nd position, so that all subsequent operations of the ***DB*1** contact are directed via the commoning of the *CN*2 arc to energize the access selector magnet (*T*). The access selector therefore commences to move over its contacts at a speed of 5 steps per sec.

At the end of the second application of the 6 sec clock pulse, relays *SB* and *SD* release, and the restoration of *SD*1 breaks the initial operating circuit of relay *ST*. *ST* releases when the *CN*1 wiper moves from normal, but relay *R* holds for the duration of the test cycle from the earth via the commoned contacts of the *CN*1 arc.

Six sec later the third application of the clock pulse again operates relay *SA*, and at the end of this pulse *SB* operates in series with *SA* as before. The first recording cycle is completed 3 sec after this time, and relay *R* is then released due to the movement of the *CN*1 wipers to the normal position. *R*1 disconnects the 5 I.P.S. pulse supply circuit. Some 2 sec later a further clock pulse (the fourth) arrives to operate relay *SD*. ***SD*1** releases *SA* and again operates *ST*. ***ST*2** now energizes the recording cycle meter for the second time, whilst the closure of ***ST*1** re-operates relay *R* via the home contact of the *CN*1 arc. The *R* contacts restart the 5 I.P.S. pulse circuit, and the access equipment commences to step on its second cycle. The recording cycles continue in this manner at 12 sec intervals until the keys are restored.

Tests on Long Holding Time Equipment. If the traffic recorder is to be used for the recording of traffic on conversational (long holding time) equipment, key *KA* is operated in addition to keys *KS* and *KC*. ***KA*1** disconnects the 6 sec clock pulse and completes the *S*-wire in preparation for the changeover of the access selectors (*TA* and *TB*) halfway through the recording cycle. ***KA*4** prepares for the operation of the *SC* relay for the same function. ***KA*2** operates relay *CO* in the control circuit, and ***CO*1** changes over the stepping circuit from uniselector *T* (short holding time tests) to uniselector *TA* (the first of one pair of long holding time access switches). Each control circuit can serve three pairs of uniselectors which are connected in exactly the same way as *TA* and *TB*, the appropriate pair for any given test being selected by means of a three-way key (see Fig. 748, Note 1). ***KA*3** connects the 30 sec clock pulse supply to the *ST* relay, and on the arrival of the first earth pulse the operation of *ST* completes, at ***ST*2**, the recording cycle meter as before. Similarly, relay *R* is operated by the closure of the ***ST*1** contact, and ***R*1** starts up the 5 I.P.S. pulse circuit for the access equipment. At the end of the first clock pulse, *ST* releases but the *R* relay remains held for the test cycle due to the earth on the *CN*1 bank. Halfway through the recording cycle, i.e. when the first access uniselector (*TA*) is positioned on contacts No. 50, the earth from ***DB*2** is extended to the *S*-lead. *SA* now operates to this earth, and at ***SA*1** prepares for the operation of ***SB*1** when the earth is removed at a later stage. ***SA*2** closes a circuit for relay *CS*, and ***CS*1** energizes the control switch uniselector magnet over the *CN*-lead.

When the wipers of *TA* step from the 50th contact to the home position, the earth on the *S*-lead is disconnected and relay *SB* now operates in series with *SA*. ***SB*2** releases *CS*, thereby allowing the control switch magnet (*CN*) to step by the removal of the earth at *CS*1. ***SB*2** also completes a circuit for relay *SC* in the control equipment, and ***SC*1** changes over the access selector driving circuit to the *TB* magnet.

When the second access uniselector has completed its recording drive, the control switch also reaches its normal position, so that relays R, SA, SB, and SC are all released. The circuit is now normal (except for the operated keys), and, when the following 30 sec clock pulse arrives (some 10 sec later), a second and similar recording cycle is made. The process continues in this manner (i.e. at 30 sec intervals) until the various keys are restored to normal.

Lay-out of Traffic Recorder Equipment. The common relays and the various control uniselectors are located on a standard 1 ft $4\frac{1}{2}$ in. apparatus rack, which is located at a central and convenient point of the exchange. The access selectors are mounted on separate racks of similar width, each rack providing accommodation for four access panels. Each panel contains 3 access uniselectors and the associated cross-connexion field. The P-wires of all the selectors are wired to a separate connexion strip at the top of each rack, and these connexion strips are in turn cabled to the connexion strips on the cross-connexion field of the traffic recorder access racks. In view of the large number of wires between the selector racks and the access racks, it is usually preferable to decentralize the recorder access racks to various points of the exchange in order to obtain the most economical cabling lay-out.

The full traffic recorder circuit contains a number of additional features not shown in Fig. 748. In the main these extra facilities are associated with the necessity for giving an alarm condition if any of the uniselectors are accidentally displaced from their proper position. This feature is necessary in view of the fact that there is a number of access uniselector arcs in parallel. Alarm conditions are also set up if any uniselector misses a step or takes two steps instead of one on any pulse. Similarly, an alarm condition is given if, due to any cause, a complete cycle of tests is not made during the time allotted for each test cycle.

Service Observation Equipment. In any telephone administration it is necessary to undertake a system of service observations in order to determine the quality of telephone service being given to subscribers. The service at the smaller exchanges is sampled during occasional visits to subscribers' premises, but this method is clearly not economical in the larger and more densely telephoned areas. On the other hand, it is not practicable to provide separate observation equipment on an exchange basis, except perhaps at the very largest centres. The most satisfactory arrangement (and the one adopted in practice) is to establish a district observation centre with facilities at the centralized point for observing the service at a number of exchanges in the surrounding district. In general, an observation centre is set up when the estimated number of calls in the area is greater than 10 000 per day, and where at least one of the exchanges has 2000 or more subscribers.

Observations are taken on the three main classes of calls:

(a) *Auto-auto Calls.* Normally only originating calls are observed, and the observations are discontinued when the observer has verified that a satisfactory connexion has been established. In doubtful cases, however (e.g. when there is poor transmission) the call may be observed throughout.

(b) *Toll Calls Routed via Automanual Exchanges.* As in the case of local calls, the observations are normally regarded as complete when an answer has been received from the operator.

(c) *Manual Exchange Calls.* It is an important feature of service observations, or in fact of any sampling scheme, that sufficient observations should be taken to ensure that the results are statistically representative of the quality of the service as a whole.

Fig. 749 shows the general arrangements of the standard centralized observation equipment. A number of subscribers' tapping relays are provided at each exchange, the actual number depending upon the total number of working subscribers on the exchange. These tapping relays are wired out to jacks on the exchange side of the M.D.F. and to similar jacks on the multiple side of the I.D.F. By means of flexible cords and plugs, it is possible to intercept the speaking pairs of any required subscriber's line on the M.D.F. and to obtain access to the P- and M-wires of the same line via the connexions on the I.D.F. The subscribers' tapping relay groups are connected to a common outgoing junction relay group, and thence via a valve amplifier to a junction which gives access to the exchange at which the observations are to be made. At the main centre each incoming junction is terminated on a group of junction relays. The junctions are associated with the observation panel equipment via a uniselector linefinder and an allotter which distributes consecutive calls to the available positions. The observation panel equipment contains various relays and a group of uniselectors for the control of the display lamps.

Each single observation panel is fitted for 10 incoming junctions. Associated with each junction are:

(a) *A junction lamp* (green) which glows at the commencement of a call, and continues to glow until the observer operates the "subscriber and

junction release" key. The circuit arrangements are such that not more than one of these lamps can glow at a time.

(*b*) *A "disconnect" key* which, when thrown, disconnects the observation junction from the panel. This key is provided for regulating the flow of calls from the various exchanges if it is found that the desired proportions are not being obtained.

(*c*) *A "hold" key* which, as its name implies, retains the connexion between the subscriber's line and the observation junction. This is necessary in order to trace back connexions.

(*d*) *An "incoming call" key.* With the key in the normal position, outgoing calls only are connected to the panel but, by the operation of the key, incoming calls as well as outgoing calls come under observation.

In addition to the above equipment per junction, the observation panel is provided with:

(*a*) *A display panel* with a capacity for the appropriate number of digits (e.g. 4, 5, or 7 as required). On outgoing calls the number dialled by the subscriber is indicated by a series of lamps behind a numbered stencil.

(*b*) *A "display release" key* for clearing the display panel after the number has been recorded.

(*c*) A *"display restore" key* to re-establish the previous number if it becomes necessary to verify the record. (This is, of course, possible only if the call is still in progress.)

(*d*) *A "subscriber release" key* which is operated to release the subscriber but to hold the junction in association with the display panel. (This key is operated when one observation has been completed but it is desired to continue to observe calls from the same exchange.)

(*e*) *A white supervisory lamp* which responds to the signals from the calling subscriber's cradle-switch.

(*f*) *A red supervisory lamp* which glows when the called subscriber (or the operator at a manual exchange) replies.

An indication is given to the observation operator of the metering on effective calls by the application of a short pulse of tone (on multi-fee calls one period of tone per pulse is received by the observation operator).

In order to obtain a true index of the quality of service, it is necessary to change the subscribers connected to the tapping relays at frequent intervals. Usually the lines are changed every alternate day and, wherever possible, observations are restricted to the more busy subscribers (i.e. those with 300 or more metered calls per half year).

The observation officer is provided with a detailed chart on which she records all details of plant faults, incorrect operating procedure, errors of the subscriber, difficulties due to congestion, and so on. These charts are summarized at regular intervals, and the results provide a representative picture of the extent and nature of the difficulties being experienced by the subscribers. The observation results are of great value in providing means whereby any tendency towards deterioration in the service can be detected and corrected.

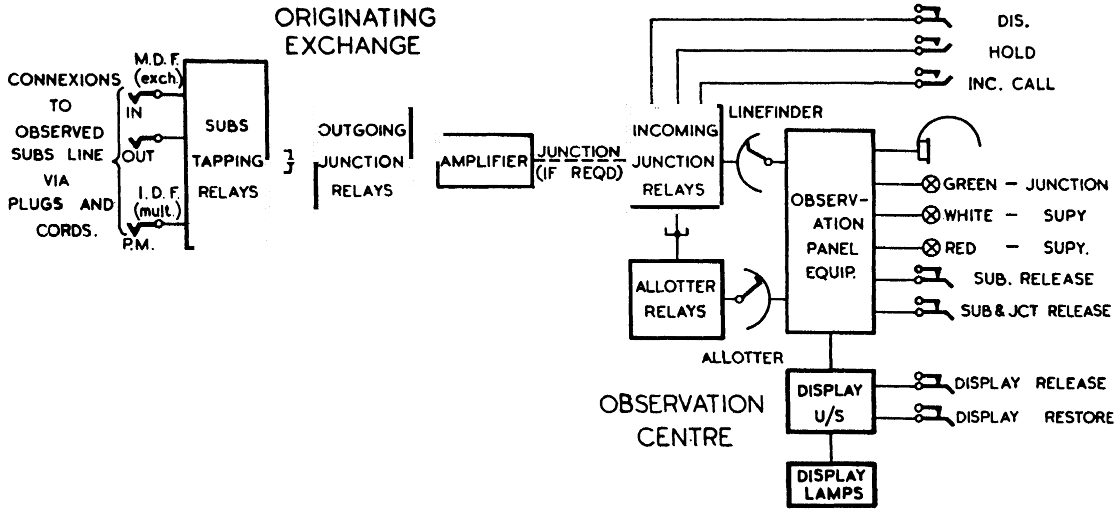


FIG. 749. GENERAL LAY-OUT OF CENTRALIZED SERVICE OBSERVATION EQUIPMENT

Subscribers' Emergency Call Service. An emergency call service is being progressively introduced at all non-director and director exchanges.

Under this scheme any subscriber (either an ordinary line or a C.C.B. user) dials a standard code 999 to obtain priority attention of the automanual exchange operator. The common emergency dialling code caters for urgent calls to the Fire Brigade, for the Police, for Ambulance, etc. The caller is routed from the 9th level of 3rd selectors via standard "0" level relay sets to the manual board. The calling lamps on the automanual switchboard are fitted with distinctive red caps, and an alarm hooter is associated with the answering equipment to ensure the prompt attention of the operator. In some cases the operators at the emergency positions are given access to the Fire Station, Police, and other emergency lines direct from the switchboard multiple without the necessity of dialling. Usually, three 999 circuits to the manual board will suffice for a single exchange but where, as in a multi-exchange area, a number of exchanges may use the same common group, then the number of emergency lines to the manual switchboard may be increased up to four or five, depending upon the number of subscribers, etc.

It is clear that the introduction of the 999 service in any particular area necessitates the modification of the dials on all the coin-box telephones within the area. It is essential that a caller using such lines should be able to obtain the emergency service without the insertion of coins, and this in turn necessitates the modification of the dial to permit of the transmission of impulses (without the insertion of coins) when the digit "9" is dialled.

The introduction of the 999 service also makes it desirable to guard against delay on mis-routed calls to adjacent selector levels. It has been seen (Chapter XII) that the 991, 992, 993, etc., dialling codes are normally allocated as faultsmen's lines to the Test Desk. If the Test Desk is not manned during the night period, it is usual to apply N.U. tone to the faultsmen's lines in order that any caller, who is incorrectly routed to a wrong level of the 3rd selectors, is given Number Unobtainable Tone.

The 999 service has not yet been extended to U.A.X.s, and subscribers on such exchanges normally obtain their emergency calls either via the parent exchange operator or by dialling the appropriate authority direct. There are a number of technical reasons why the emergency service, by the dialling of the standard code, cannot be given from U.A.X.s but, nevertheless, the 999 code is reserved at all exchanges with a view to ultimate developments.

Night Service Facilities for P.B.X.s. It has been seen in earlier chapters of this Volume that, by the dialling of intermediate numbers in a P.B.X. group (or, in larger P.B.X. groups, by the dialling of a special number), it is possible to cut out the P.B.X. hunting feature of the final selectors. The subscriber can therefore connect certain of the exchange lines to special extensions where calls will be received during the period when the P.B.X. is not staffed. These normal night service facilities require that the caller should dial a particular number in order to obtain access to a required night service extension at the P.B.X. Some subscribers require facilities whereby any caller can dial the normal directory number of the P.B.X. and be routed to the appropriate night service extension without the need for special night service numbers.

A facility is available (known as Class A night service) whereby some of the lines (normally the first two) of the subscribers' group are diverted to the automanual switchboard, whilst the remaining lines are busied at the final selector multiple. The lines are terminated on multiple answering equipment which is lamped only on the night concentration positions at the exchange. Night service extensions are connected to the appropriate exchange lines at the P.B.X., and the main exchange operator has details of these connexions. On receipt of an incoming call, she ascertains from the caller the particular department required, and completes the call by dialling the appropriate night service number. In exceptional cases direct access to night service extensions is provided from the automanual switchboard.

A somewhat simpler night service scheme (Class B service) provides for the busying on the final selector multiple of all the exchange lines in a P.B.X. group which are not connected to night service extensions. Thus, any caller who dials the directory number of the P.B.X. is connected without discrimination to the exchange lines which are extended at the P.B.X. to night service extensions. During periods of light traffic, the caller will seize the first night service exchange line but, if this is engaged, the final selector will continue to hunt over the remaining night service exchange lines.

The switching to night service conditions is effected by means of relays in the automatic exchange. If the automatic plant is in the same building as the automanual switchboard, the night service relays are controlled by means of a key in the cable turning section. Where the automatic equipment is not in the same building, there is a dial controlled switching scheme, whereby the operator dials one code for setting up night

service conditions, and another for restoring the lines to normal.

Subscribers' Transfer Service. In some cases a subscriber makes a request for all the incoming traffic to his regular number to be diverted to some other telephone for a specified period. There are several ways of providing this facility.

When the automatic equipment is in the same building as the automanual switchboard, it is possible to transfer service by means of a key fitted in the cable turning section. The operation of this key connects all incoming traffic to the subscriber's normal line to the automanual switchboard via the changed number interception equipment (q.v.). The use of a transfer key in the cable turning section is not generally practical where the automatic equipment is in a separate building from the automanual switchboard. (Any such scheme would involve the use of junctions between the two.) In such circumstances a dial controlled switching scheme is employed. At the appropriate time for transfer of service, the telephonist dials a special number over the trunk offering switching train to the exchange concerned. The code digits used are usually outside the ultimate numbering range of the subscribers' numbers. The positioning of the trunk offering final selector operates relay equipment, which diverts the line to the interception equipment. When normal service is to be restored, the operator dials a different number which restores the line to normal working conditions. The circuit arrangements are such that an engaged line is not diverted until the termination of the call in progress. In both the above schemes any call can be originated from the normal telephone during the period of interception. Provision is made for the temporary transfer (or interception) of one or more lines from a P.B.X. group. The remaining lines of the P.B.X. which are not to be intercepted are engaged on the final selector multiple.

If a transfer of service is required for a prolonged period, it is usual to alter the connexions on the exchange M.D.F. so that incoming calls for the regular number are automatically routed to the required transfer number. This scheme does, of course, prevent originating calls from the regular number during the period of transfer.

Temporary Restriction of Service to Subscribers. Occasions sometimes arise when it is necessary to restrict the subscriber's telephone service for the non-payment of accounts, subscriber absent from home, and other reasons. In some cases it is desired to prevent a subscriber originating calls, but to permit incoming calls to be completed in the usual way. Such a condition is known as originating calls barred (O.C.B.). In other circumstances it may be desirable to interrupt temporarily both the incoming and the outgoing service to the subscriber. Any line so disconnected is said to be temporarily out of service (T.O.S.).

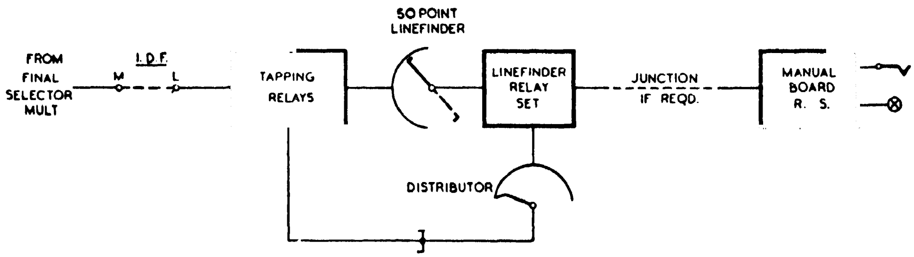


FIG. 750. BLOCK SCHEMATIC OF SERVICE INTERCEPTION EQUIPMENT

The O.C.B. facility is usually provided by inserting a small paper sleeve over the subscriber's line relay contact springs, thereby preventing the operation of the linefinder or the subscriber's uniselector. If the line is to be made T.O.S., it is usual to insulate the contact springs of the cut-off relay (subscriber's line circuit) and to insert an insulating wedge into the M.D.F. protector springs associated with the positive line. The negative line is also disconnected by a special plug and cord by means of which it is possible to apply N.U. tone to the subscriber's line.

The N.U. tone supply is connected to battery so that the ring-trip relay is operated when the line is seized by a final selector. It is, of course, important that there should be no loop across the negative and positive wires (or a battery on the positive wire). Such conditions would operate the *D* relay of the final selector and register the call against the originating subscriber.

Service Interception and Changed Number Equipment. Service interception equipment is usually provided at all except the smaller U.A.X.s for the interception of incoming traffic to a subscriber. The facility may be required for a number of reasons such as, for example, where a subscriber's number has been changed, where a

subscriber complains of incoming calls not intended for him, and so on.

There are two types of interception equipment:

(a) Full facility service interception, and

(b) Changed number interception.

In each case a number of tapping relay groups is provided at the automatic exchange (Fig. 750). Each of these tapping equipments can be temporarily connected to any subscriber's line as required. At director and non-director exchanges the number of tapping equipments for full facility interception is approximately 0·2 per cent of the total lines on the exchange. The number of changed number tapping equipments varies from 0·75 per cent to 1·5 per cent of the number of exchange lines. The tapping relay groups are connected to the banks of a linefinder, the wipers of which are connected to a junction which terminates on the automanual switchboard. At sleeve control exchanges the interception junctions are accommodated on the Enquiry suite, and each junction is provided with a calling lamp and answering jack in the multiple answering field. Each interception linefinder will accommodate up to a maximum of 25 tapping equipments for service interception, or up to a maximum of 50 changed number equipments. If the total number of tapping equipments (service plus changed number) is 25 or less, then they are usually combined in one mixed group which utilizes a common group of interception junctions. It is usual, however, to provide separate groups for service and changed number interception when the total number of tapping equipments is greater than 25. The number of linefinders and junctions in each group is determined by the volume of anticipated traffic.

Meter Observation Equipment. Meter observation equipment is normally fitted at all medium and large automanual exchanges. If, as a result of disputed local accounts, it is decided to place a subscriber's line on the meter observation equipment, connexions are made in the automatic switchroom to the meter observation equipment on the manual switchboard. Each circuit contains three lamps (known as the "meter," "subscriber's," and "incoming call" lamps), a meter and a listening key (Fig. 751).

The meter lamp (which is fitted with a white cap marked *R*) glows when the observation meter and the subscriber's meter are operated.

The subscriber's lamp (fitted with a plain white lamp cap) glows whilst the subscriber's receiver is off the rest, and is inoperative whilst the speaking key is thrown.

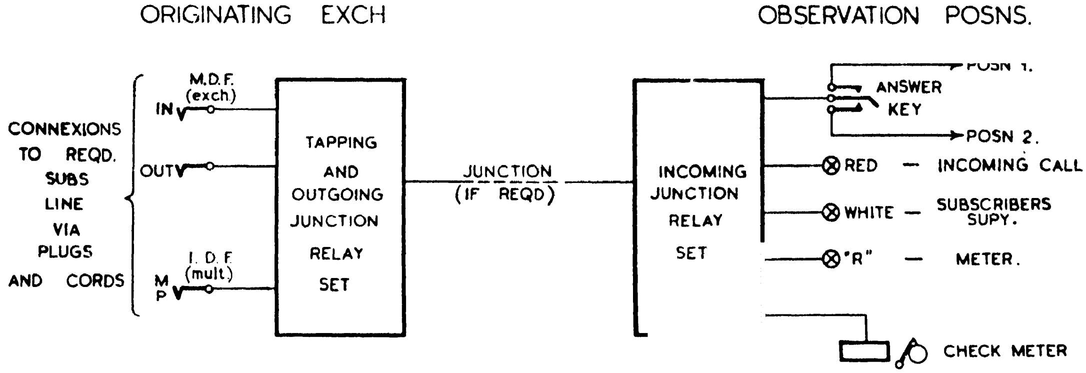


FIG. 751. GENERAL ARRANGEMENTS OF METER OBSERVATION EQUIPMENT

The incoming call lamp (red lamp cap) glows on receipt of an incoming call until the subscriber answers.

The circuit is arranged so that the meter on the observation equipment operates once on each effective call, but does not operate on ineffective or on incoming calls. The operation of the listening key connects the line under test to the operator's telephone circuit and at the same time cuts out her transmitter.

When a circuit is placed under observation, simultaneous readings are taken both of the subscriber's meter and of the observation equipment meter. The meter readings are compared at intervals for as long as is desired, in order to check for correct operation.

Test Number Circuits. Special circuits are provided at most automatic exchanges so that the operators on the automanual switchboard and at dialling-in exchanges can test the switchboard dials and the junction circuits. Fig. 752 shows the circuit arrangements. A final selector number is allotted to each circuit. This number should, for preference, contain the digits 1 and 0 to provide for testing the performance of the dialling circuits on

short and long impulse trains. When the equipment is seized by the final selector, relay *A* operates to the earth on the *P*-wire, and at **A2** applies continuous ringing to the tone winding of the impedance coil (*I*). At the same time contact **A1** connects relay *B* via a resistor to the interrupted ringing supply. Relay *B* is operated in accordance with the normal interrupted ringing cycle (i.e. it is operated for 0·4 sec, released for 0·2 sec, operated for 0·4 sec, and released for 1 sec). The *B*1 contact controls relay *BA* which is provided with a heel-end slug so that the relay holds during

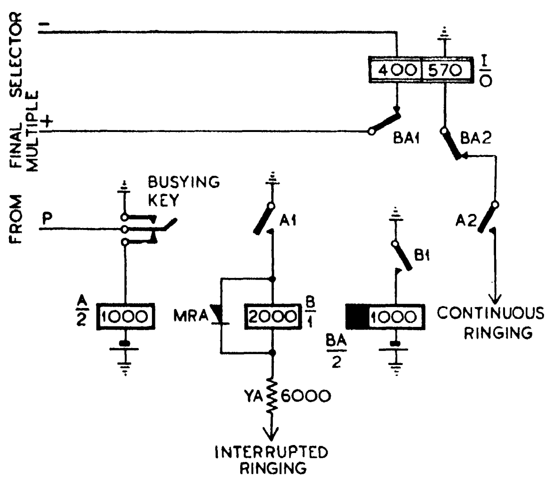


FIG. 752. TEST NUMBER CIRCUIT

the short release of relay *B* between the two successive applications of ringing (i.e. it has a release lag greater than 0·2 sec). The *BA* relay is therefore operated for approximately 1 sec and released for a period of 2 sec. **BA2** interrupts the circuit of the tone coil of *I*, and thereby removes the tone from the speaking pair. The tone heard by the operator is an induced e.m.f. of ringing frequency which is applied for 2 sec, and disconnected for 1 sec. This gives a distinctive signal to the telephonist that the test number circuit has been picked up and also acts as a rough check of the circuit from a transmission point of view. Contact **BA1** interrupts the line winding of impedance *I*, thereby breaking the loop for 1 sec in 3. This provides a distinctive flashing supervisory signal to the manual exchange operator and proves the satisfactory operation of the supervisory side of the circuit under test.

It should be noted that the test number circuit would provide metering conditions if dialled from an ordinary subscriber's telephone. The circuit must therefore not be used by subscribers' faults-men, etc., who may wish to test the dial at a subscriber's premises.

At non-director exchanges, it is usual to provide one test number circuit per 1000 lines of multiple. In director exchanges the test number circuits are often placed as a group accessible from a 2/10 P.B.X. final selector. In these circumstances the digits 1 and 0 should appear in the first 3 digits of the number.

Special Faults Circuits. A call from one automatic subscriber to another may be routed via a very large number of alternative paths through the exchange. If trouble is encountered, it is not easy to locate the faulty equipment unless the call is held. In this connexion, the tracing of faults can be much facilitated by the provision of a quick means of communication between the telephonists and the engineering maintenance staff. To help in this co-operation it is usual to provide one or more special faults circuits at all exchanges of more than about 900 lines. Apart from their use in the tracing of faulty equipment, the special faults circuits also provide ready means whereby the telephonist can request the engineering officer to trace back any call routed to the manual board.

The special faults circuit is terminated on a telephone located near the subscriber's uniselector or 1st linefinder racks. Each telephone is equipped with a buzzer calling signal to ensure prompt attention.

At exchanges of medium size, the special faults circuit is given a final selector number and the telephonists, maintenance control officers, etc., set up a call to the automatic exchange maintenance man by dialling the final selector number. At the larger exchanges (and in practically all cases where there is an automanual switchboard in the same building) it is usual to provide joint access between the outgoing junction multiple of the switchboard and the final selectors of the automatic equipment.

Graduated Howler. A howler circuit is provided in all large public telephone exchanges in order to draw the attention of a subscriber to the fact that his receiver has not been replaced on the cradle. In a manual exchange a howler circuit is terminated on a plug located on the testing position, and can be applied to any line as required merely by plugging into the appropriate multiple jack. Of necessity, the note produced by a howler circuit is very loud and is liable to cause discomfort or damage to the ear of any subscriber who may be listening. In order to guard against the sudden application of the full howler volume, the howler circuit at an automatic exchange is so arranged that

the volume is gradually built up over a period of some 12 sec.

Fig. 753 shows typical circuit arrangements. A howler jack is provided on each 1st selector rack, and can be connected to any selector as required by means of a flexible cord. The insertion of the plug into the howler jack operates relay *ST*, and the changeover of the ***ST*2** contacts completes a circuit for relay *X* to the earth on the auxiliary springs of the jack. ***ST*4** applies the *Y* relay to lead No. 3 of the howler circuit. If the uniselector the uniselector driving magnet, so that the switch is stepped at the rate of one contact every 1·5 sec. As the *H*1 wiper moves round the bank, the shunting resistors are gradually cut out of circuit so that the tone increases up to its maximum volume after 8 steps of the uniselector. When the wipers of the *H*2 arc step on to the 9th contact, the drive circuit is broken, and the tone remains at the full volume until such time as the circuit is released (i.e. until relay *Z* restores). The restoration of *Z*2 now allows the mechanism to return to its normal

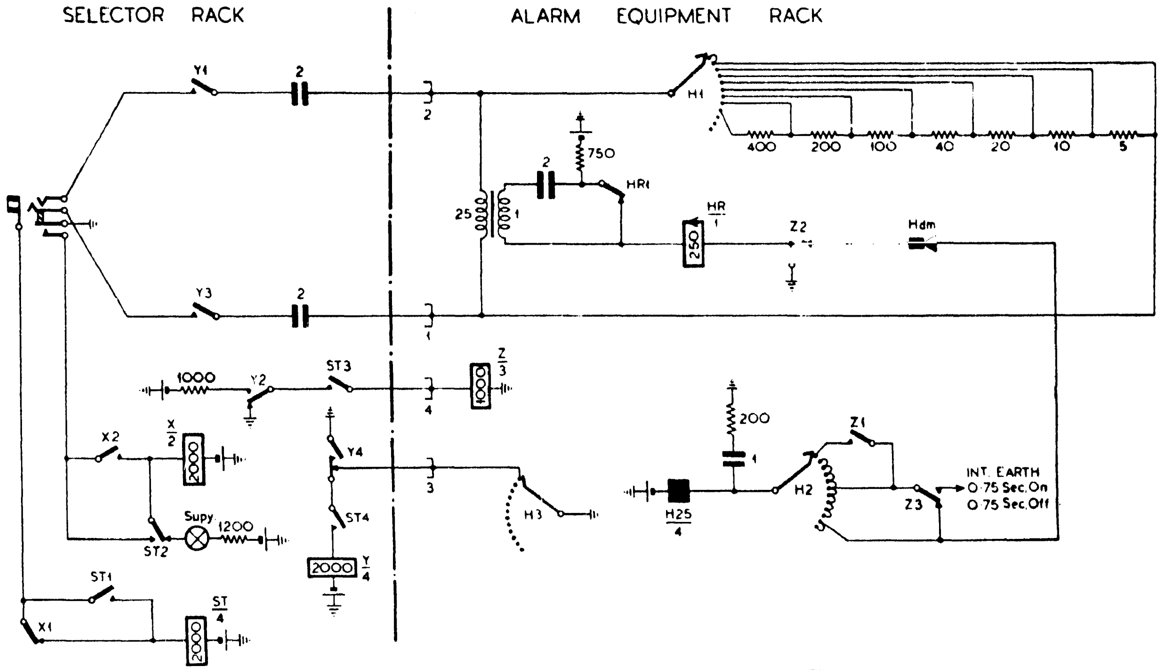


FIG. 753. CIRCUIT ARRANGEMENTS OF GRADUATED HOWLER

in the howler circuit is normal, earth is extended via arc *H*3 to operate relay *Y*, and the latter holds at **Y4** independently of the *H*3 earth. Contact **Y2** applies a battery to lead No. 4 in order to energize the start relay *Z* in the howler circuit. At the same time contacts **Y1** and **Y3** extend the − and + wires to the howler tone circuit.

The operation of **Z2** energizes the buzzer *HR* which vibrates due to the self-interruption of its circuit at ***HR*1**. During each operation of this contact, the 2 μF capacitor is alternately charged and discharged, and the resultant current surges pass through the primary winding of the induction coil. At this stage the tone induced into the secondary winding is short-circuited by wiper *H*1 of the uniselector.

Contacts **Z1** and **Z3** apply interrupted earth to position. The circuit is so arranged that, once relay *Z* has released, it is not possible to re-seize the howler circuit until the uniselector reaches its normal position.

Meter Reading Circuits. It is the usual practice to record the readings of the subscribers' meters at an automatic exchange by visual inspection of the meters. In some circumstances (especially when there is considerable noise in the apparatus room), a greater accuracy in meter reading can be obtained if the readings are dictated over a special telephone to a recording officer in a suitable room (often the exchange clerical room). Meter reading circuits are fitted only at the larger non-director exchanges, and at most director exchanges (on account of the greater noise in the apparatus room).

Where the recording point is in the same building as the subscribers' meters, a direct circuit

is provided and is terminated at each end on an instrument jack. Where the recording point is in a building remote from the automatic exchange, it is not usual to provide direct circuits, but each meter reading circuit is connected to a final selector number. In such cases connexion is established by the dialling of the meter reading circuit number from the clerical room.

Meter Test Circuits. Apart from the routine engineering tests, it is usual to provide a meter test circuit which can be used for observing the operation of any particular subscriber's meter where complaints of false registration have been received. Meter test circuits of this type are installed only at telephone exchanges where the manual board is in the same building as the automatic plant. The equipment consists of two telephones fitted side by side close to the meter rack.

One telephone (designated *A*) is required for originating calls, whilst the second instrument (designated *B*) is used as a called telephone for providing the metering condition. Telephone *B* is permanently connected to a spare final selector number, whilst telephone *A* is wired to jacks on the M.D.F. The originating or meter test telephone (*A*) has associated with it a test key and a busy lamp. The test key is so wired that, with the key normal, the line under test is routed direct to its normal calling equipment. When the key is thrown, telephone *A* is connected to the subscriber's calling equipment, whilst the actual subscriber's line is diverted to a spare calling equipment which is permanently wired to the test key. The lamp operates whenever the line under test is engaged.

When it is desired to make a test on any particular line, say number 2345, the meter test jacks on the M.D.F. are connected via a plug and cord to intercept the line on the protector of the M.D.F. If subscriber number 2345 is engaged, the lamp associated with telephone *A* will glow and the tests are deferred until such time as the call is completed. When the line becomes free, the test key is operated, thereby connecting the subscriber's line to the spare calling equipment (so that he can make calls during the period of the test). At the same time telephone *A* is connected to the normal calling equipment of number 2345. The meter permanently associated with number 2345 is read, and a number of test calls is made between telephone *A* and telephone *B* to ensure that the meter operates correctly when the call is answered at telephone *B*. It may so happen that calls may be made from the subscriber's line during the period of the test and, in order to debit such calls, readings are taken of the meter associated with the calling equipment to which the line is switched during test. It is clear that if there are any incoming calls during the period of the test, busy tone will be returned to the caller unless at that time the receiver of telephone *A* is on the cradle-switch.

Alarm System in Automatic Exchanges. It has been shown in previous chapters that various alarms are provided to indicate abnormal conditions on the automatic switching plant. Usually a lamp is provided to indicate the alarm condition on any individual selector or relay set. The tracing of the faulty circuit is facilitated by the provision of rack (and sometimes shelf) alarm lamps. In addition to these local alarms, it is the normal practice to provide a comprehensive system of floor alarms in order to direct the maintenance staff to the appropriate part of the exchange.

Each floor in an automatic exchange is divided into areas, known as *sections*. Each section covers an area of some 3000 sq ft and is further subdivided into subsections. The subsections are, as far as possible, arranged so that they include similar classes of equipment, and each subsection usually covers an area of up to 700 sq ft. Whereas the individual rack alarms indicate the exact alarm conditions (e.g. permanent loop, release failure, called-sub.-held, etc.) the floor alarms are merely classified into two groups—prompt and deferred. Release alarms, fuse alarms and the like are connected to the prompt alarm system, whilst, on the other hand, the permanent loop alarms, called-sub.-held alarms, etc., are of a less urgent character and are wired to the deferred alarm system. Keys are provided for disconnecting certain deferred alarms from the main fault system when so desired.

Two alarm lamps are provided per subsection —a white lamp for the deferred alarm condition, and a red lamp for a prompt alarm. The lamps are mounted at a conspicuous point in an aisle, and in such a position that the lamp clearly indicates the subsection to which it refers. It is usual to locate all the subsection lamps of one section in the same aisle. A panel is provided on each floor with lamps for each section on that floor. Any fault in a section is indicated on this panel by the red illuminated number of the section. A further lamp panel is provided on each floor of the exchange so that, if an alarm condition exists on any floor, an indication is given on all the other floors of the exchange.

The power plant of an exchange is treated as one section and is distinguished throughout the floor alarm panels by the adoption of a blue number panel in the alarm lamp units.

If necessary the floor and section alarm indicating panels are duplicated up to a maximum of four appearances on any one floor in order that the panel shall be visible to the maintenance officers from the normal working locations.

In addition to the lamp system, a floor bell is fitted near the alarm lamp panel to draw attention to the fact that an alarm lamp is glowing. If necessary, these bells are duplicated at a number of points on the floor so that the alarm can be heard above the noise of the apparatus. Section bells are also provided if any floor contains a large number (say, more than three) sections.

Facilities are provided to extend all the alarms to the test desk or to the manual board during periods when the apparatus rooms are not staffed. The switching is effected by means of an "alarm extension key" on the test desk, or in the cable turning section of the manual switchboard. The operation of this key disconnects the audible alarms of the apparatus rooms and extends the prompt and deferred lamp signals to the manual board or test desk.

Special care should be taken in the design of an exchange to ensure that the battery supply to the main alarm system is not fed through common distribution fuses which also serve the regular automatic equipment. Separate and independent fuses fed directly from the busbars are necessary to avoid the liability of a fuse being blown by a fault on the regular automatic equipment which the alarm equipment is intended to supervise.

Two-party (Shared) Service. Party lines, where two or more subscribers share the same line to the exchange, were a common feature of the earlier manual systems. As the manual exchanges were converted to automatic working, continuance of the party lines presented some technical difficulties and, until recently, it has been the policy in this country to discourage the use of party line working in automatic areas.

The drastic cuts in the provision of external plant during the war years have produced a situation where there is an acute shortage of external cable pairs in most telephone areas. It will be some years before the present situation can be rectified, and in the meantime there is a long list of applicants awaiting telephone service. Party line working provides a partial solution to this very acute problem, and will in future be adopted where necessary for providing service to residential subscribers. The use of multiple or rural type party lines, where a large number of subscribers can be connected to the same pair of wires, presents some difficulties with the current standard automatic system due to the fact that code ringing is required from the final selector. It is therefore intended that party lines on automatic systems shall be restricted to two subscribers, i.e. two-party service.

The desirable features of a two-party service at an automatic exchange are:

(*a*) The second subscriber should not be disturbed when one subscriber is being rung for an incoming call.

(*b*) The bell at the second station should not tinkle when the first subscriber is dialling on an outgoing call.

(*c*) Separate automatic metering should be provided for both subscribers.

(*d*) If possible a single-line circuit at the exchange should suffice for both subscribers.

(*e*) Any auxiliary apparatus, either at the exchange or at the subscriber's premises, should be simple, inexpensive, and capable of manufacture in quantity within a short period.

If secrecy is required, the circuit arrangements are considerably complicated and necessitate either the use of a carrier system of transmission or the provision of a switching relay at the point where the two spurs are teed to the common exchange line.

Various designs of meter discrimination circuit have been in existence for some considerable time but, generally speaking, the circuits are rather complex (and hence expensive) and are somewhat liable to failure as a result of mis-operation by the subscriber, or other abnormal conditions. Some of the meter discrimination circuits are based upon the fact that one party presents a loop calling signal, whilst the second party offers an earthed loop to the exchange. Other circuits have been designed to produce the meter discrimination signal from a fleeting earth when one subscriber lifts his receiver. Still other circuits effect discrimination during dialling, e.g. one subscriber transmits loop disconnect impulses, whilst the other subscriber transmits earth or earth disconnect impulse trains. At the present time laboratory tests and field trials are in process on a number of meter discrimination circuits. It is hoped that a satisfactory circuit employing no more than three relays per party line will be evolved.

An interim system of two-party service with meter discrimination has been designed which does not necessitate additional equipment at the automatic exchange. The elements of this scheme are illustrated in Fig. 754. The two subscribers are known as the "*X*" and "*Y*" stations. On an incoming call to the *X* station, ringing current is

applied to the B-line (i.e. normal ringing conditions), the X station bell being connected via the usual capacitor to the B-line. The Y station is called by the application of ringing current to the A-line and, of course, the bell circuit at this station is connected to the A-line.

Both telephones are provided with a calling press button. The press button at the X station connects earth to the B-line, whilst the button at the Y station applies earth to the A-line. Two subscribers' calling equipments are required at the exchange. The normal earth connexions to the positive line (at the K contacts) are removed and the two calling equipments are connected in parallel with a reversal of the negative and positive wires to one of them. The cross-connexions are so arranged that the line relay in the calling equipment of the X subscriber can be operated from an earth on the B (negative) line, whilst the line relay of the Y subscriber's calling equipment can be operated only by an earth on the A (positive) line.

Either subscriber originates a call by depressing the calling button on his telephone before lifting the handset. The subsequent removal of the handset from the cradle extends this earth on the appropriate wire to operate the correct line relay at the exchange. In due course the subscriber's uniselector seizes a 1st selector and dial tone is returned to the caller. The button can now be released. It will be noted that, although the initial calling signal is an earth on one wire, the normal loop-holding and loop-disconnect dialling principles are retained once the call has been switched to a 1st selector. The initial earth calling signal is, of course, required to determine which line circuit (and consequently which meter) shall be used on a particular call.

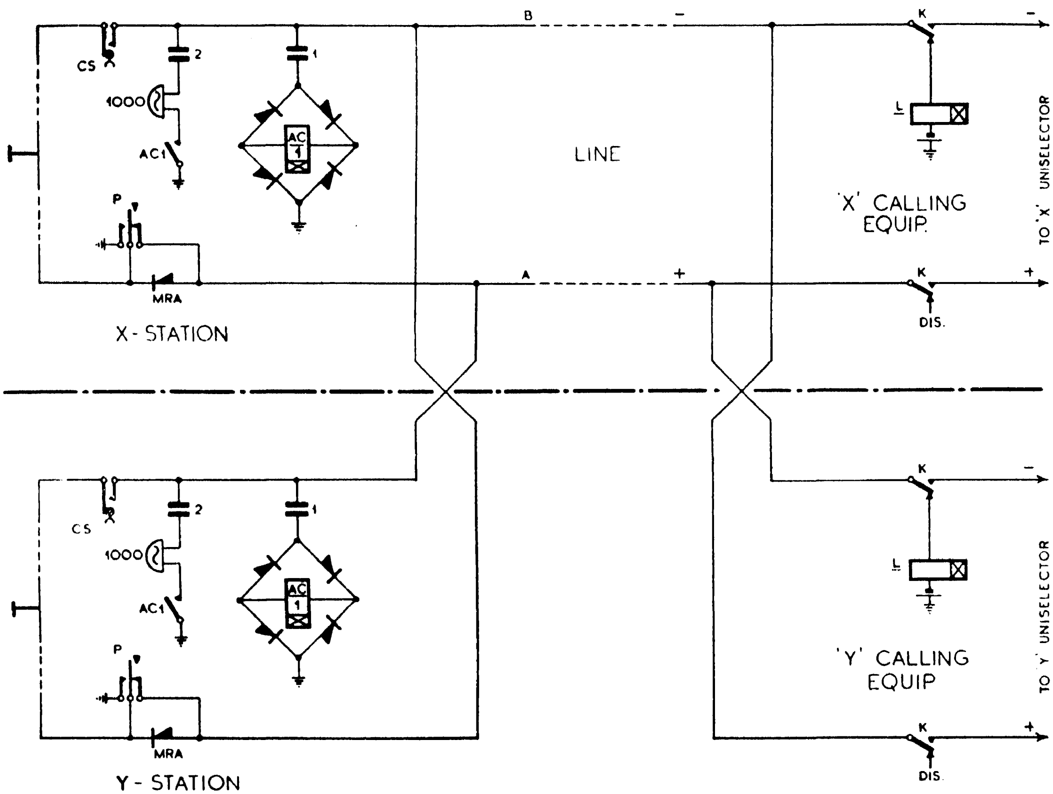


FIG. 754. TWO-PARTY SERVICE WITH SEPARATE METERING

Bell tinkling of the other party's bell during dialling (and flashing on calls to the manual board) is prevented by the provision of a slow-to-operate relay in a full-wave rectifier bridge in each subscriber's bell set. This ensures that the bell is disconnected until the relay has operated to full ringing current. The rectifier (*MRA*) in the subscriber's telephone circuit is provided to prevent the transmission of a false impulse when the calling button is released. The rectifier is short-circuited when the press button is in its

normal position but, when the button is depressed, the rectifier is introduced into the telephone loop in the direction which allows the calling earth to be effective on one wire only.

The circuit arrangements of Fig. 754 provide an economical two-party service without the need for additional equipment at the exchange. There is, however, a number of difficulties which may occur in the event of mis-operation by the subscriber. If, for example, both subscribers attempt to make a call simultaneously, and then one of the parties replaces his receiver, the call made by the subscriber who retains the line may be made via the other subscriber's calling equipment, thereby resulting in incorrect metering. Similarly, if, due to a line fault or a failure to replace the handset after an incoming call, there is a loop on the line when either subscriber depresses the calling button, conditions are established for both subscribers' calling equipments to be taken into use. In this event, two 1st selectors are seized and both are locked to each other via the reversed line connexions between the two subscribers' calling equipments. This lock-up will persist until it is cleared by the engineering staff at the exchange. A similar lock-up can also occur if both subscribers initiate a call simultaneously, but the probability of this occurring is not very great. The probability of lock-up is greatly increased if a subscriber first removes the receiver and then waits for an appreciable time before depressing the calling button. For this reason the subscriber is specially instructed to press the button before lifting the receiver.

Due to the liability of lock-up, the simple circuit arrangements of Fig. 754 are restricted to use in exchanges at which regular daily engineering attendance is provided. The lock-up can be prevented by the provision of a simple 2-relay circuit which is inserted between the line and the two calling equipments and provides change-over contacts so that it is impossible for both calling equipments to be taken into use at the same time.

EXERCISES XXV

1. Describe how access is gained from the test desk via automatic equipment to a subscriber's line for testing purposes and explain, with the aid of circuit diagrams, the functions of the special selectors concerned. (*C. & G. Telephony, Grade III*, 1946.)

2. Enumerate the operating facilities afforded by trunk offering circuits.

Explain, with the aid of a diagram of the circuit elements concerned, how an operator using a trunk offering circuit is enabled (*a*) to offer a trunk call on a line which is already engaged, and (*b*) to obtain a signal when the called subscriber replaces his receiver so that the trunk call may be connected. (*C. & G. Telephony, Grade III*, 1941.)

3. What do you understand by "routine testing"? Discuss the various methods by which routine tests can be carried out, and the field of application of each method.

4. Describe the general arrangements of a typical automatic routiner. Show by means of simple diagrams how the routiner can be associated with the equipment under test and how it is possible to arrange for automatic consecutive testing of all the equipment in the exchange.

5. Give a test element suitable for use in a final selector routiner for the verification of the selector ringing and ring-trip circuit. How is the routiner made to step on to the next test if the results of this particular test are satisfactory?

6. Describe the arrangements made in an automatic exchange for measuring, automatically, the traffic flow. Indicate by means of a sketch how the recording meters and the selectors are connected to the traffic recorder.

If the congestion meter associated with a subscriber's uniselector grading indicates overloading, but a record of the traffic flow indicates otherwise, explain how the automatic traffic recorder may be used for investigating the conditions in more detail. (*C. & G. Telephone Exchange Systems III*, 1949.)

7. What is meant by "Class A" and "Class B" night service? Describe the arrangements which make it possible to switch the lines of a P.B.X. to night service conditions from a remote manual centre. What happens if the subscribers' lines are engaged at the time of switching?

8. Enumerate the facilities provided by the Centralized Service Observation Equipment. What is the purpose of this equipment and how is it used?

9. Describe the system of alarms normally provided in an automatic exchange. Which particular conditions are classified as "prompt" alarms and which as "deferred" alarms?

10. Describe, with the aid of diagrams, how it is possible to provide a two-party service at an automatic exchange with facilities for separate metering. Explain any limitations of the circuit and how these can be overcome.

CHAPTER XXVI

THE CONVERSION FROM MANUAL TO AUTOMATIC WORKING

VERY few parts of Great Britain are completely without telephone facilities, and hence most new automatic exchanges are required to replace existing manual systems or to provide relief to nearby exchanges. The character and volume of traffic on the old network are, therefore, often a valuable guide as to the probable traffic on the new automatic system.

Before any new automatic exchange is brought into service it is necessary to prepare a detailed and long term plan in order that preparations can be made in adequate time for the various operations required in connexion with the transfer. Detailed and accurate estimates are required of the probable number of subscribers' lines at the opening date and of the volume of traffic and its distribution. On this basic information a building of suitable size is designed and erected, and automatic equipment is ordered, manufactured, and installed. The exchange design must also make provision for the normal growth of the area, so that expensive modifications and rearrangements do not become necessary at a later date.

When the new exchange has been designed and installed, arrangements must be made for the changing over of existing lines to the new system and for the rigorous testing of the new plant before it is brought into service. All the work in connexion with the transfer to the new system must be carried out without interrupting the service to existing subscribers.

The design of an automatic system is highly specialized work which requires considerable experience and a thorough knowledge of the trunking principles, the switching circuits, and the physical design of the exchange. In the following paragraphs of this chapter a brief description is given of the more important stages in the design and opening of a new automatic exchange.

Planning Periods. It is clearly undesirable to install only sufficient equipment to meet the requirements at the opening date of the exchange. Some provision must be made in the initial installation for growth during the first few years of the life of the exchange. The provision of a large quantity of spare equipment is, on the other hand, very wasteful and unnecessarily increases the annual charges of the exchange equipment. Some types of equipment can be installed quickly and without the expenditure of much labour. The margin of spares on such equipment can therefore be kept at a low level, thereby reducing the quantity of ineffective plant. On the other hand, certain parts of the equipment require a considerable amount of engineering work during the manufacture and installation, and it is uneconomical to add small portions of such equipment at frequent intervals. In every case there is an optimum planning period for each part of the exchange design in order to give the most economical arrangement over a number of years.

The planning periods are, as far as possible, standardized in order to simplify design procedure. In general the periods adopted are:

(*a*) The exchange numbering scheme is designed to meet the anticipated growth for 30 years beyond the opening date of the exchange.

(*b*) The exchange building is designed to meet the anticipated development for a period of 20 years from the opening date.

(*c*) The requirements for junction routes are calculated for a period of 10 years.

(*d*) Apparatus racks, selector banks, and the main internal cabling of the exchange are designed to last for a period of 5 years from the opening date.

(*e*) Selectors and jacked-in relay sets are provided to meet the requirements of the first 3 years of the exchange life.

Site and Accommodation Data. The first major step in the provision of a new automatic exchange is the preparation of data from which it is possible to purchase a suitable site and to proceed with the design of the exchange building. For the larger exchanges the accommodation data must be prepared five years or more before the required opening date, but this period is, of course, reduced for the smaller exchanges (particularly exchanges of the "unit" type in standard buildings).

The first step in the preparation of the data required for the building and its site is a close study of the probable telephone development in the area concerned. In the course of this study a detailed survey is made of the area, all the existing properties are classified, and as much information as possible is obtained on probable developments in the various districts. From this study it is possible to estimate the total number of subscribers and their distribution throughout the area at the

opening date and at the 5-, 10-, 20-, and 30-year periods from that date.

The results of the development study are examined by the engineer responsible for the provision of the external plant, and fundamental plans of the external cabling scheme are prepared. It is now possible to plot on a map the theoretically best location for the new exchange which will give the most economical lay-out of external plant. It is rarely possible to find a vacant and available site at the theoretical centre of the area, and hence a map is prepared to show a suitable "area of search" which will be satisfactory from an external cabling point of view.

The subscribers' development figures are now examined from the point of view of the exchange design. Information is obtained as to the probable calling rate of the subscribers and on the anticipated volume of traffic to other nearby exchanges. A tentative numbering scheme for the new exchange is also prepared at this stage. Sufficient data are thus available to determine the approximate floor area required for the automatic switching plant and its associated power supply. To this is added the accommodation required for manual switchboards, for engineering workrooms, welfare accommodation, and so on. The complete estimate of the total floor area required at the 20-year period, together with a copy of the "area of search" map is now available for a search to be made for a suitable site.

Control Sheets. It is, of course, not possible to proceed with a detailed plan for the provision of the new exchange until a suitable site has been acquired. The obtaining of a satisfactory site makes it possible to initiate a long term programme for the various operations connected with the transfer. This plan is drawn up in the form of a *control sheet*, on which all the more important dates are entered. On the building side, target dates are fixed for the preparation of plans, for the production of working drawings, etc., right up to the final completion date for the building work. A further series of dates are entered for the preparation of the necessary traffic data which will form the basis of the exchange design, and these dates are supplemented by further dates for the preparation of the engineering specification, for manufacture, for the commencement of installation, and so on.

The control sheet also provides a planning medium throughout the installation of the new exchange and, in fact, covers all the more important steps right up to the date of transfer. The control sheet is designed so that it is possible to maintain a constant watch on changes in the dates for the various stages, and is the main method of co-ordination throughout the work.

Initial Equipment Data. At the appropriate time a complete and detailed study must be made of the traffic requirements at the new exchange. It has been stated that equipment racks, cabling, etc., are provided to meet the 5-year development figure, and hence the initial requirements of the exchange are based on the development figures for the 5-year period beyond the opening date. Selectors and certain relay sets, on the other hand, are provided only to meet 3 years' growth, and a correction factor (usually of the order of 0·95) is used to indicate the 3-year requirements of such circuits.

This basic information from which the engineering design is set up is prepared in the form of *initial traffic data*. When completed, the traffic data give full information on:

(*a*) The total busy hour originated traffic (in T.U.s) both for ordinary lines and for coin-box lines.

(*b*) The busy hour calling rate for originated traffic both for ordinary and for coin-box lines.

(*c*) The busy hour incoming calling rate for ordinary subscribers and for various classes of P.B.X. subscribers.

(*d*) The average holding time.

(*e*) The numbering scheme for the exchange.

(*f*) Details of the number of lines and of the volume of incoming traffic to large (i.e. 11-and-over) P.B.X. subscribers.

(*g*) A detailed analysis of the originated traffic.

(*h*) A detailed analysis of the incoming traffic to the exchange.

(*i*) An estimate of the junction requirements.

(*j*) If an automanual board is required, details are supplied of the number of positions, the size of the answering and of the outgoing multiples, call timing facilities, etc.

(*k*) Any other special facilities, i.e. changed number interception, service observation, meter observation, etc., etc.

In order to prepare the initial equipment data, certain information is required in addition to the subscribers' development forecast. This subsidiary information is obtained from the six-monthly call valuation records taken at the old manual exchange, from the six-monthly traffic records, and from the monthly record of busy hour traffic. It is usual to apply a standard figure of 2·6 min for the holding time on local calls, although this standard figure may be modified to meet the requirements of the individual exchange.

Preparation of Switching Details. The engineering design of the new exchange must first commence with the preparation of a satisfactory trunking scheme and the calculation of the quantity of switching equipment required to meet the anticipated traffic. Typical trunking diagrams are available which show the general lines on which exchanges of various types should be designed, but these trunking schemes are, of course, modified if necessary to meet the particular requirements of each exchange. When a tentative trunking scheme has been decided, it is possible to proceed with the calculations to determine the number of switches, banks, and racks required for the various stages of selection. To facilitate these calculations traffic capacity tables have been prepared to show the number of trunks required to carry various volumes of traffic at the standard grade of service. These tables cater for gradings of various availabilities (e.g. 10, 20, 24, etc.) and for full availability conditions. (See Appendix I.)

In the course of many years of experience, certain rules have been formulated for design work in order to meet the various engineering requirements and to safeguard against expensive engineering rearrangements if the actual development of the area varies from the anticipated figures. The following aspects are of particular interest:

(1) Subscribers' uniselectors are provided on the basis of one per subscriber's line, the number being rounded up to the next multiple of 20. The uniselectors are divided into a "coin-box" group and an "ordinary" group, each group being trunked to separate 1st selector groups. When arranging the equipment on the racks, space is normally left for the ultimate requirements of the "coin-box" group before commencing the "ordinary" group of uniselectors.

(2) A separate grading to the T.D.F. is provided for each block of 2000 subscribers' lines. This limitation is necessary to prevent undue complexity in the tracing of calls and to avoid overhearing difficulties on the later choices.

(3) 200-outlet group selectors are now standard for all exchanges, and the latest design provides grading facilities at the rear of the rack (see Chapter IV). Each rack is equipped with a full complement of banks (i.e. 60 or 80 depending upon the height) and partially equipped racks are not usually considered. Each pair of shelves is cabled out separately to the grading strips at the rear of the rack so that the minimum size of each grading group is automatically determined (i.e. 20 selectors). The cabling between the racks and the equipment I.D.F. is also standardized and does not require individual design.

(4) At non-director exchanges the 1st selectors are provided in several distinct groups according to the class of traffic carried (i.e. coin-box traffic, ordinary traffic, operators' traffic, U.A.X. traffic, and so on). This segregation is necessary in order that levels can be divided as required to meet the differing requirements of the various groups. It is usual to place the "coin-box" group on the lower shelves of the 1st group selector rack, but it is not necessary to allow space for the 20-year development of this group before commencing the "ordinary" group of 1st selectors.

(5) 200-outlet final selectors are now standard for all exchanges. The banks are provided in units of 20, 30, 40, etc., to 80 and, in determining the appropriate size of bank multiple, due allowance must be made for the provision of test and trunk offering final selectors.

(6) In the determination of the final selector bank capacity, it is necessary to allow some margin to guard against an unanticipated rise in the incoming calling rate. If, for any reason, the calling rate rises during the life of the exchange to such an extent that the multiple provided at the outset will no longer accommodate the selectors, it would be necessary either to reduce the number of lines in the final selector group or, alternatively, to provide additional multiple capacity (with tie cables) at some other point in the exchange—both alternatives are very undesirable. A margin of safety is provided by allowing a somewhat larger multiple than the calculated figure from the traffic capacity tables.

(7) The exact distribution of the subscribers' lines over the final selector groups is not known at the design stage. It is assumed, however, that all "ordinary" subscribers are equally divided amongst the available final selector groups and that the maximum loading will be 188 subscribers per 200-line group. This leaves a 6 per cent margin to cater for ceased and unavailable lines.

(8) The same problems apply in respect of 2/10 P.B.X. final selector groups where there is no knowledge at the design stage of the ratio of ordinary and P.B.X. lines. For purposes of calculation it is assumed that the maximum loading of such groups will be 132 ordinary lines and 56 P.B.X. lines, i.e. it is assumed that there will be 12 spares for ceased, etc., lines.

(9) The 11-and-over type P.B.X. final selector groups are individually designed on account of the large variations of traffic which occur between different groups.

When the design has been completed, the detailed calculations of switch quantities, etc., are summarized on various diagrams and charts. The more important of these are:

(1) *Trunking Diagram.*

(2) *Switching Details.* These forms indicate the initial number of switches, banks, and racks for each stage of selection, and the ultimate number of racks of each type.

(3) *Rack Equipment Charts.* These charts show the disposition of the equipment on the uniselector, group selector, and final selector racks.

(4) *T.D.F. Charts.* These show the grouping of the shelves and cabling of the bank multiples to the T.D.F., together with details of the cables between the T.D.F.s and the I.D.F.

(5) *Grading Charts.* These charts show the actual commoning of the various grading groups at the T.D.F.s or rack grading points.

Preparation of Specification. The exchange design is now sufficiently far advanced to proceed with the preparation of a detailed specification for the equipment. In all but exceptional cases standard circuits are used, and the design of the various apparatus racks is laid down in a number of standard equipment specifications. Preparation of the exchange specification can be facilitated by the use of schedules of all the standard circuits, equipment drawings, and specifications, so that the engineer can prepare a specification for a new exchange by selecting those items which he requires for a particular exchange. From the information given in the "switching details" and rack equipment charts, he can determine the quantities of the various classes of circuit, the number of each type of rack, and so on. He must also make provision for the many miscellaneous requirements of the exchange (e.g. service interception equipment, observation equipment, testing facilities, alarm scheme, etc., etc.).

It is not possible to determine the exact I.D.F. requirements at this stage of the design, and certain empirical rules are therefore used to determine the appropriate size of the I.D.F. The specification engineer must also consult the line plant engineer to obtain information concerning the number of verticals required on the M.D.F. In addition, information is required concerning the power supply for P.B.X.s in the area, the testing facilities required, and so on. Particular attention must be paid to the junction requirements and the methods of signalling in order that the appropriate relay sets can be provided.

A careful study of the lay-out of equipment is of prime importance. A good initial design may save a considerable expense in rearrangements of the equipment at a later stage in the life of the exchange. The design must not only make provision for the anticipated development of the exchange, but must also be as flexible as possible to meet unforeseen requirements. A good design can, moreover, considerably facilitate maintenance, and result in a more satisfactory service.

Estimation of Power Plant Requirements. It is usual to employ standardized data for use in estimating the current consumption at automatic exchanges to enable the appropriate size of power plant to be provided. The total current consumption of an exchange may be considered as comprising:

(*a*) the switching and conversation load, which depends entirely on the volume of traffic; and

(*b*) a miscellaneous day load (usually smaller than the switching, etc., load) to make allowance for such current drains as line leakage, testing, P.B.X. power supply, and so on.

Switching and Conversation Load. The quantity of switching equipment is designed to carry the busy hour traffic, and the maximum load during the busy hour can be estimated by the use of consumption factors which have been calculated for all the main units of equipment. The consumption factor is quoted in ampere-hours and is the product of the current taken by the equipment and the average holding time. There is a very large number of different types of circuit in an automatic exchange, and the calculation of the load by the preparation of consumption factors for each individual type of circuit would tend to be somewhat cumbersome. In order to simplify the calculations, it is usual to quote consumption factors only for the main items of equipment, these factors being weighted to compensate for the current drain of the less important circuits. The following are the usual items considered in the determination of the load:

Item	*Consumption Factor* Ah per item
First Code Selector	0·22
Multi-metering Satellite 1st Selector	0·22
Group Selector	0·30
Final Selector	0·24
Relay Set	0·05
Manual Board Position	1·20

The busy hour load (in ampere-hours) is obtained by multiplying the factors shown in the above

table by the total number of each item of equipment. The busy hour load so obtained is multiplied by the "day to busy hour" ratio (q.v.) to give the total daily ampere-hour consumption for switching and conversational requirements. (When the day to busy hour ratio is not available, a figure of 7 is normally used.)

There is a number of items, such as 2 V.F. signalling equipment, for which no consumption factors have been produced. Where there is a material quantity of such equipment, special consideration must be given to the case.

Miscellaneous Day Load. The miscellaneous day load is substantially directly proportional to the number of direct exchange lines. The miscellaneous day load (in ampere-hours per day) is given by 0·08 times the number of direct exchange lines. The sum of the day loads for switching, etc., and for miscellaneous requirements gives the total day load for the exchange.

It is usual to reserve sufficient floor space to meet the power plant requirements based on the estimated load at the ultimate (20-year) period. The number of lines and the estimated quantity of switching equipment at the 20-year period are ordinarily available from the design data. The initial load and the load at intermediate times during the life of the exchange are determined from a growth factor which assumes an even growth in the number of lines from the opening date to the ultimate date. The charging machines initially installed are designed to meet the busy hour load 5 years after the opening of the exchange. The batteries are usually plated with sufficient capacity to meet the total day load at the 10-year period. The main discharge cables and the size of the battery boxes are, on the other hand, designed to meet the requirements at the 20-year date.

The counter e.m.f. cells required for P.B.X. power leads are provided to meet the estimated current consumption at the ultimate period. To assist in the calculation of the current drain, it is usual to subdivide the P.B.X.s into three main groups, viz. small, large, and multiple type. The average current drain for each of these groups is assumed to be 0·05, 0·33, and 1·7 Ah respectively.

Positive battery is required at most exchanges, either for metering or for miscellaneous purposes. Where positive battery metering is employed, a 10 Ah battery will suffice for exchanges of up to 6000 lines ultimate, whilst a 20 Ah battery will normally meet the requirements of larger exchanges. If the positive battery is used merely for miscellaneous purposes (e.g. in a director exchange), a 10 Ah battery is normally employed.

The ringing machine must be of sufficient capacity to supply the maximum demands for ringing current and should have adequate reserve of power for tones, etc. The machine installed initially is normally of adequate capacity to meet the requirements at the 20-year period. For purposes of calculation, the capacity of the ringing machine is evaluated in terms of the number of incoming calls to the final selector units together with an allowance for generator signalling relay sets and P.B.X. ringing leads.

Opening Date Requirements. Some months before the opening of a new automatic exchange it is necessary to prepare various schedules to show how the equipment will be connected up to meet the requirements at the opening date. A detailed list of the subscribers to be connected on the new exchange must be prepared, and the allocation of the calling equipments must be decided. In allocating the uniselectors to individual subscribers, consideration must be given to:

(*a*) the balancing of the load (as far as possible) between the groups of the uniselector gradings, and

(*b*) the length and run of the jumpers on the subscribers' I.D.F. (Careful allocation of the calling equipments makes it possible to have short, straight jumpers for a large number of subscribers.)

In addition to the subscribers' jumpering arrangements, the exact number of junctions on each route must be determined, and also the method of working these junctions (i.e. unidirectional or bothway). If there is an automanual switchboard, it is also necessary to decide upon the allocation of the individual circuits in the answering and outgoing junction multiples, the grouping of the lines for F.L.S., and so on.

Acceptance and Call-through Tests. It is the usual practice in the British Isles for all exchanges (other than the smaller U.A.X.s) to be installed under contract by the telephone manufacturing companies. As installation proceeds, detailed and comprehensive tests and inspections are carried out by a Post Office "Clerk of Works" to ensure that the equipment is in accordance with the specifications. These tests vary, of course, with the type of equipment, and include such items as:

General inspection of the apparatus.
Resistance check of relay coils and selector magnets.
Bank alignment checks.
Continuity and reversal tests on bank multiples.
Relay adjustment checks.
Mechanical adjustment checks.

Functional tests.
Check of routining facilities.
Transmission tests.
Insulation tests.
Check of lubrication.
Final inspection.

When all the selectors, relay sets, wiring, etc., have proved satisfactory on the sectional tests, and when all jumpers have been completed and checked, an overall *call-through test* is carried out to ensure that the exchange is in a satisfactory condition and is ready for public service. It is necessary, for the call-through test, to station a testing officer at each switching stage of the exchange. Thus, in a director exchange, one engineer is required at the uniselector racks, one at the final selector racks, one at each stage of code and numerical selection, one at the A-digit selector racks, and one at the director racks. There is also a co-ordinating officer who takes charge of the whole operations. Generally speaking, a minimum of eight testing officers are required for director exchanges, and five or six for non-director exchanges. A testing programme is prepared in advance, and each officer concerned in the tests is given detailed instructions of the duties required of him as the test proceeds.

The test is so designed that calls are made from each uniselector grading to every group of final selectors in the numbering scheme. In a non-director exchange the number of calls to be passed during the test is at least equal to the number of local 1st selectors. In a director exchange the number of calls is equal to the number of 1st code selectors. A calling telephone is connected to any uniselector on the first rack in the first grading. A call is now made from this telephone to the test number (99) of the first final selector group. The call is answered by the engineering officer at the final selector racks, and a check is made that the call is satisfactory. The connexion is released and the calling officer observes that the uniselector associated with the calling telephone homes satisfactorily. All the selectors used on this first call are now artificially engaged by the personnel located at the intermediate selector racks. The calling telephone is now transferred to another uniselector on the same rack, and a call is made to the test line of the next final selector group. A test call is made as before and, after release, all the switches used on the call are busied. This process continues until the calling uniselector hunts continuously due to the fact that all outlets have been engaged. A check is now made to compare the conditions with the grading charts.

At this stage the calling telephone is transferred to a uniselector on the next rack, and the testing continues until all the outlets from the second rack have been engaged. A condition is ultimately reached when all the outlets in the first grading have been used and continuous hunting occurs when any attempt is made to pass further calls from any uniselector rack in the grading. The same procedure is adopted for the testing of the next and subsequent gradings of uniselector outlets. If any fault is encountered during the tests, the train of switches is held and the fault is passed for attention.

As the tests proceed, conditions may arise where all the selectors available in a given group have been used but further calls are required to complete the testing of the outlets to 1st selectors. In these circumstances, it is usual to disengage all the selectors in the congested group and to repeat the process of busying each selector after every subsequent test call.

The automatic equipment associated with incoming junctions is tested by originating calls from the I.D.F. and by adopting a procedure similar to that described above. Similarly, a complete series of tests is carried out on the outgoing junction routes, and on the circuits to the automanual switchboard.

In most instances, the engineering call-through tests are supplemented by a series of "flood" tests with artificial traffic. For these tests a number of temporary telephones is installed in a suitable room and a group of telephonists passes calls from these telephones in a predetermined sequence.

Transfer of External Lines. There is a number of different ways of arranging for the simultaneous transfer of working subscribers' lines from an existing to a new exchange. The method to be used in any particular case depends largely upon the relative locations of the two exchanges and the disposition of the line plant. There are three recognized arrangements, viz.:

(*a*) Teeing of the lines at the new exchange (*internal teeing*).

(*b*) Use of break jacks in the old and new exchanges.

(*c*) Teeing of the cable pairs in the underground system (*external teeing*).

In some cases one of the above methods will suffice for the transfer of all the lines, but in other instances the most economical arrangement necessitates the use of two or all three methods together.

The changeover arrangements are designed so that all working lines can be transferred to the new exchange more or less simultaneously at the time scheduled for the transfer. It is important

that full protection should be provided to the lines and to the exchange equipment during the transition period, and facilities must be available for the testing of individual lines prior to the transfer. Telephone circuits are required between the old and the new exchanges for the control of the transfer operations, and these circuits must be wired so that the control lines are not disconnected when the old exchange is cut out of service.

Internal Teeing. If the underground cables serving all the working subscribers pass close to the new exchange en-route to the old exchange, it is readily possible to divert all the subscribers into the new exchange building (Fig. 755). The cable pairs are terminated on fuse mountings in the usual manner, and temporary wiring is provided to maintain the continuity between the subscribers and the existing exchange. Each subscriber's line is jumpered to the appropriate number at the new exchange, but is disconnected from the exchange equipment by the insertion of wedges *B*. A separate pair of wedges is used for each subscriber's line, and the wedges are connected together by means of a cord which passes through a hole in each wedge. The cord is fixed at its upper end to a point above and in front of the protectors, so that the whole of the wedges for a complete vertical can be withdrawn rapidly at the time of the transfer. The cord should be of sufficient length to allow individual wedges to be withdrawn for any line tests which may be necessary prior to the transfer.

Wedge-shaped strips of hardwood (*A*) are provided at the old exchange so that, at the time of the transfer, the subscribers can be disconnected from the old exchange equipment by the insertion of these wedges into the test springs of the protectors. Individual insulating wedges per line are not necessary at the old exchange, and the hardwood strips are therefore made of sufficient length to disconnect 20 lines per strip, i.e. there is a pair of wedges per protector mounting. At some of the older exchanges, the protectors do not provide testing facilities, and in these cases it is necessary to withdraw either the heat coils (or, exceptionally, the fuses) at the time of the transfer. Where the heat coils are to be withdrawn, it is usual to pass a length of strong tape round each strip of 20 heat coils. The tape should be tied to the first and last heat coil in the strip, and sufficient length should be left hanging loose to facilitate withdrawal.

In some cases only a proportion of the subscribers at the existing exchange are to be transferred to the new exchange. Such conditions arise when an additional exchange is opened in order to take over part of the area previously served by the old exchange. In these cases the subscribers' lines to be transferred are often scattered over the multiple side of the M.D.F. at the old exchange, and it is not possible to use hardwood strips as described above. It is, moreover, not possible to use individual insulating wedges owing to the time which would be taken to insert these wedges at the time of the transfer. A special plug has been designed for use in these circumstances. The insertion of this plug into the protector test springs transfers the continuity of the circuit from the contact springs of the protector to contacts inside the plug. The contacts of the plug are held together by a small wedge which is inserted in the plug prior to the transfer. The plugs, complete with wedges, are inserted into the protectors prior to the transfer, and the wedges are connected together by means of string, so that all the wedges can be withdrawn rapidly at the time of the transfer.

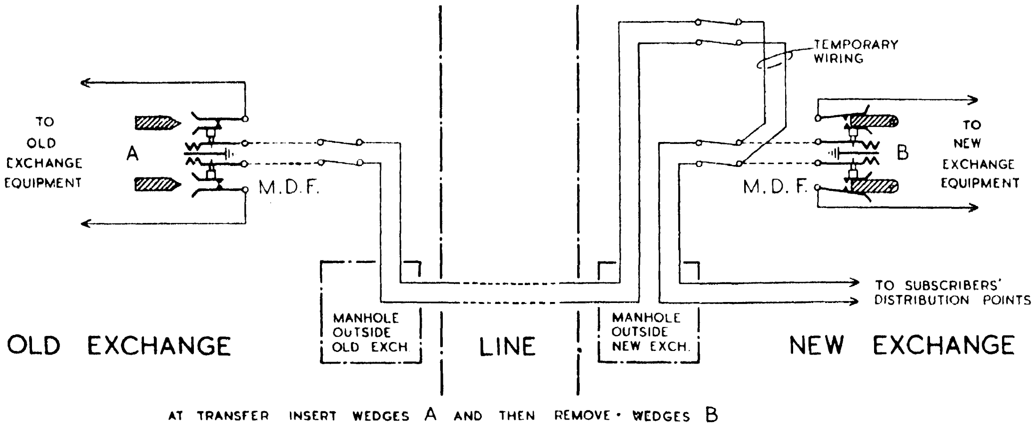


Fig. 755. Simple Changeover Scheme with Internal Teeing

The wiring and construction of the protectors at some of the older exchanges are such that there is sometimes a danger of the lines being earthed when the heat coils are withdrawn at the transfer. It is important that any such possibility should be carefully examined before the date of the transfer and suitable arrangements made for avoiding faults. In some instances it may be desirable to withdraw the carbon blocks from the protectors on the day before the transfer.

When the time of transfer arrives, the controlling officer (who is normally stationed at the new exchange) gives orders for the old exchange equipment to be *cut out* (i.e. for wedges *A* to be inserted.) When, and only when, this operation is completed, he gives instructions for the new exchange to be *cut in* (withdrawal of wedges *B*). The subscribers' lines are now working to the new exchange equipment, whilst the old exchange is completely isolated.

There are not many cases in practice where all the subscribers' lines pass through the new exchange manhole as shown in Fig. 755. There are many instances, however, where the most economical arrangement is to re-route the lines via the new exchange prior to the transfer, which permits of the use of the internal teeing scheme described above. Fig. 756 shows a typical case where two suitable manholes are selected for the diversion of the lines to the new exchange. For purposes of illustration, it is assumed that an 800-pair cable passes through manhole *A*, and a 600-pair cable through manhole *B*. It is necessary to run cables between the two manholes and the new exchange, and the size of these cables is often greater than the existing cables in order to cater for anticipated development. It is assumed that a 1000-pair cable is led from manhole *A* to the new exchange, and an 800-pair cable from manhole *B* to the new exchange. During the weeks prior to the transfer, the working pairs are routed via the new cables and temporary tees at the new exchange as shown in the centre diagram. It is clear that this scheme necessitates the use of two pairs per working line between the interception manholes and the new exchange.

The lower portion of Fig. 756 shows the arrangements after the completion of the transfer. There is one practical difficulty in the adoption of this scheme. The work of diverting the pairs through the new exchange must be commenced some time before the date of the transfer, and, in order to make provision for any new subscribers' lines which may be installed during the transition period, it is necessary also to divert a limited number of spare pairs from every distribution point. If abnormal growth occurs at any particular

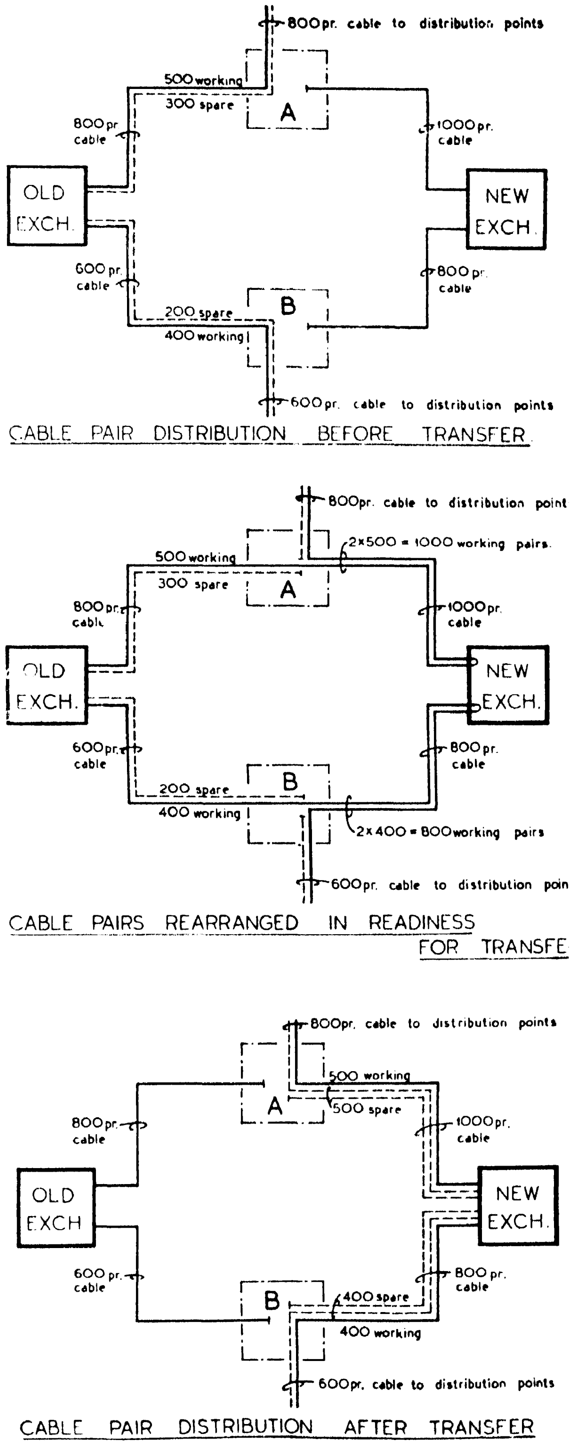


Fig. 756. Re-routing of Subscribers Via New Exchange in Readiness for Transfer

distribution point, then it may be necessary to re-open the joints to divert additional pairs through the new exchange.

Use of Break Jacks. In some instances it is not possible to divert the circuits via the new exchange without providing underground cables of a size greater than is justified by the normal development forecast. Fig. 757 shows an alternative method of planning the transfer by the use of temporary break jacks at the old and new exchanges. The arrangements are such that the cable pairs between the two exchanges are used for carrying subscribers' lines to the old exchange prior to the transfer and then, after the transfer, for routing other subscribers' lines to the new exchange. The lines are divided into two groups:

Group 1, which consists of those lines which do not pass the new exchange (e.g. subscriber No. 1 in Fig. 757).

Group 2, which includes those lines which pass the new exchange en-route to the existing exchange (e.g. subscriber No. 2 in Fig. 757).

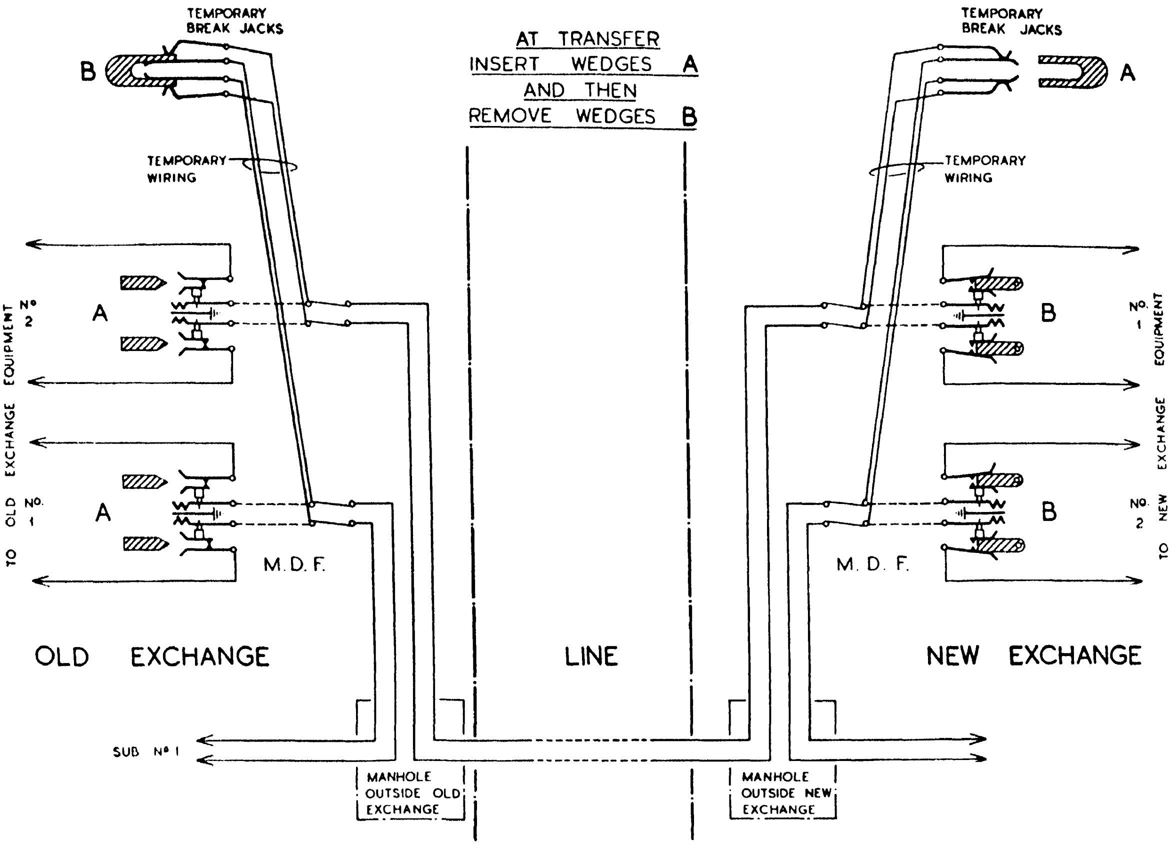


FIG. 757. TYPICAL TRANSFER SCHEME USING BREAK JACKS

Each line in group 1 is associated with a line in group 2 so that, by the switching arrangements indicated in Fig. 757, the two lines are prepared for the transfer.

The cable pairs of lines in group 2 are diverted through the new exchange M.D.F. so that they work, prior to the transfer, via temporary break jacks at the new exchange. Each line in group 1 is temporarily wired via another set of break jacks at the old exchange to its associated line in group 2. The cable pairs are jumpered to the correct protectors on the exchange side of the new exchange M.D.F., but are isolated from the new equipment by wedges *B*. Similarly, the lines in group 1 are disconnected from the circuits with which they have been associated by means of insulating wedges (*B*) in the temporary break jacks at the old exchange. At the time of the transfer, the old exchange is cut out by the insertion of wedges *A* in the protectors at the old exchange and in the temporary break jacks at the new exchange. When this operation is completed, the withdrawal of wedges *B* at the old exchange

extends the lines in group 1 to the new exchange, whilst the removal of wedges *B* at the latter connects all the lines to the new exchange equipment. After the transfer the cable pairs of subscribers in group 1 are connected through at the old exchange manhole, so that all lines are completely isolated from the old exchange. As in the previous cases, the preparations for the transfer should allow for growth during the transition period.

External Teeing. If the number of cable pairs available and the disposition of the plant is such that the internal teeing or break jack schemes cannot be employed, it is possible to prepare the lines for transfer by teeing the circuits in the underground system as shown in Fig. 758. External teeing is particularly applicable where a high proportion of the subscribers' lines concentrate at points between the old and the new exchange. New cables are laid between the new exchange and one or more selected manholes. The working lines are then teed to pairs in the new cables, but the lines are isolated from the new exchange equipment by the insertion of protector wedges *B*. At the time of the transfer the old exchange is isolated by the insertion of wedges *A* at the old exchange, and then by the withdrawal of wedges *B* at the new exchange.

External teeing has been used successfully at many large transfers and is often the most economical method. It is highly desirable that the manholes selected for the teeing points should be dry.

Work at Subscribers' Installations in Readiness for Transfer. Any transfer of an exchange system from manual to automatic working involves either the modification of the apparatus at the subscribers' premises or its complete replacement. Wherever possible, the arrangements should be such that there is no interruption of service at the transfer, i.e. the subscribers should be able to obtain service via the automatic equipment from the moment of the changeover. There are three basic methods of modifying the subscribers' apparatus in readiness for a changeover to automatic working.

The first method is based on the principle of modifying the apparatus so that it will work satisfactorily on the manual system up to the time of the transfer, and then will be suitable for automatic working without any further modifications or rearrangements. This method has the following advantages:

(*a*) The work at the subscribers' premises can be completed as one operation prior to the date of the transfer.

(*b*) It avoids the provision of dual equipment and switching arrangements, which often cause service difficulties at the time of the transfer.

(*c*) It overcomes any objections by subscribers to the presence of two telephone instruments for some time prior to the changeover.

(*d*) In most circumstances it is the most economical method.

In some cases the work merely consists of adding a dial to the manual type instrument but, where this is not possible, the old instrument is recovered and a new automatic type instrument is fitted in its place.

A second method is to provide a new automatic telephone alongside the existing apparatus with suitable cross-connexions so that the subscriber can use the automatic instrument after the time scheduled for the transfer without the need for any keys or other switching device. The old instrument is recovered as soon as possible after the transfer. Generally speaking, this method is less desirable than the scheme described above, but it may be necessary in some cases where it is impracticable to use an automatic type telephone

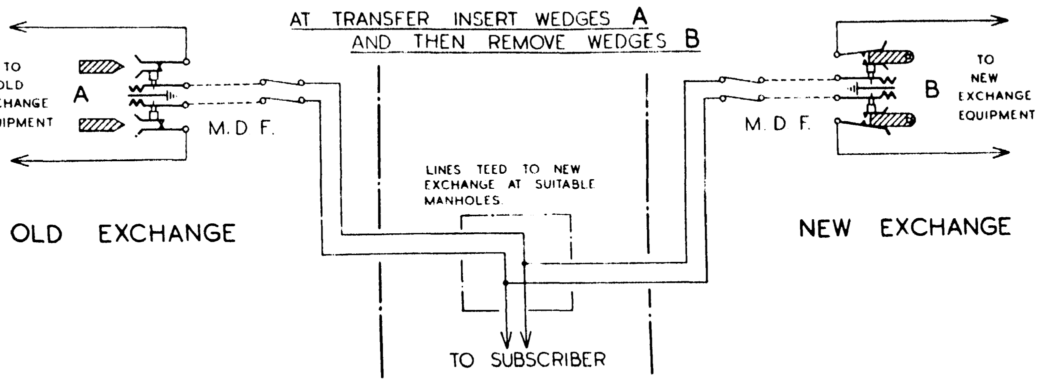


FIG. 758. TRANSFER SCHEME WITH EXTERNAL TEEING

prior to the transfer. Where this method is adopted, it is normal practice to install the new automatic type instrument in its permanent location and to find temporary accommodation for the old instrument during the transition period.

If neither of the above methods is possible, it may be necessary to resort to the provision of a changeover key at the subscriber's premises. This key is operated by the subscriber at the time of the transfer to switch the exchange line from the old manual to the new automatic type instrument. Generally speaking, changeover keys are very undesirable and often result in confusion at

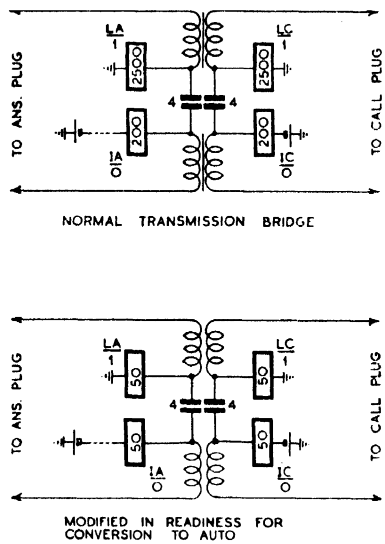


Fig. 759. Modification of C.B.S.2 Cord Circuits to Permit Use of Auto Instruments Prior to Transfer

the time of transfer. Their use is restricted to exceptional cases where it is impossible to find other methods of transfer.

Conversion from C.B. to Auto. The Central Battery System employs a loop for calling and a disconnexion for clearing, together with the use of a central battery for the supply of current to the subscribers' transmitters. These basic signalling and transmission features are retained in the standard automatic system, and hence, when the conversion is from C.B. to automatic working, the modifications at the subscribers' premises usually consist of the fitting of a dial to the existing telephone. Some of the older C.B. instruments do not make provision for the fitting of a dial, and in these circumstances it is necessary to change the instrument. The subscriber is instructed not to use the dial until the time of the transfer, so that the new instrument behaves as an ordinary C.B. telephone until the changeover.

Conversion from C.B.S.2 to Auto. The C.B.S.2 System also employs the loop-calling and disconnect-clearing principle, but requires the use of local batteries for the energization of the subscribers' transmitters. The normal signalling current on the line is insufficient to allow the replacement of the L.B. instruments by automatic type telephones unless arrangements are made to increase the signalling current from the exchange to a value suitable for central battery transmission instruments. The conversion of the exchange equipment to provide this facility is comparatively easy. The top portion of Fig. 759 shows the normal transmission bridge and signalling relays of a C.B.S.2 cord circuit. By replacing the signalling relays and impedance coils by new relays and coils, each of 50 Ω resistance (as shown in the lower part of Fig. 759), the necessary transmitter current can be provided without in any way interfering with the operation of the cord circuits. Generally speaking, this is the best method of carrying out a transfer from a C.B.S.2 system, since all the subscribers' instruments can be changed to the automatic type prior to the transfer and no second visit is required subsequent to the changeover. Before the scheme can be applied, however, a careful study must be made of the current demands on the manual exchange power plant during the transition period.

Occasionally, where it is not possible to modify the C.B.S.2 circuits to give central battery transmission, it is necessary to make special arrangements at the subscribers' premises. The newer type of local battery instrument provides for the fitting of a dial. These instruments will work quite satisfactorily after the changeover to automatic working but, of course, retain the local battery transmission circuit. It is possible therefore to fit a dial to the instrument prior to the transfer and then to visit the subscribers' premises again subsequent to the changeover to replace the instrument by one of the correct automatic type. The older local battery instruments used on the C.B.S.2 system make no provision for the fitting of a dial, and in these cases it is necessary to install an automatic type instrument alongside the existing telephone. The instruments are connected in parallel but with the bell of the local battery instrument disconnected at a suitable point. The principle of disconnecting the L.B. instrument bell circuit when a new instrument is connected in parallel is of some importance, especially where a "Plan Number" exists. The presence of two (or perhaps more)

bells in parallel may produce premature ring-trip conditions after the changeover to the automatic system. More important, an additional bell circuit across the line introduces a considerable amount of impulse distortion which may cause wrong numbers on outgoing calls. In addition to this, bell tinkling would be produced on the old instrument during dialling from the new automatic telephone.

Conversion from C.B.S.1 Working. C.B.S.1 exchanges utilize a loop from the subscriber to call, and an earth on the *A*-wire to clear. This earth clearing feature of the C.B.S.1 system makes it somewhat more difficult to modify the exchange equipment for the use of automatic type instruments during the transition period. The C.B.S.1 non-multiple type switchboards (see Vol. I) employ $1000 + 1000\,\Omega$ supervisory indicators and a capacitor-impedance type transmission bridge in the cord circuit. To modify the cord circuits for C.B. transmission, it would be necessary to replace the supervisory indicators by $50 + 50\,\Omega$ relays, and to modify the circuit so that these relays respond to the loop and *disconnexion* signals from the subscriber's telephone. (The connexions can be arranged so that, during the transition period, the earth clearing signal from the C.B.S.1 instruments is ineffective.)

The bush of the subscribers' line jacks on a non-multiple C.B.S.1 switchboard is not normally used, and this absence of a sleeve conductor circuit makes it impossible to provide positive clearing signals under the control of the cord circuit line relays. There are only two possible alternatives: The first is to connect earth to the bushes of the subscribers' jacks, and to provide sleeve relays in every cord circuit. Make contacts of these sleeve relays, in conjunction with break contacts of the transmission bridge relays, would enable positive clearing to be retained when the board is modified for C.B. transmission. The other alternative is to tolerate a system of negative clearing during the transition period. (This is usually undesirable because it is liable to cause confusion to the operators.) If this latter course is decided upon, it becomes necessary to disconnect the supervisory signals from the exchange alarm circuits and also to modify the connexions which provide the through clearing signal on incoming junction circuits.

The same basic problems exist on C.B.S.1 multiple type switchboards, but the subscribers' lines of such switchboards are normally provided with an earth connected resistor in the bush circuit. Thus, by the provision of sleeve relays in the cord circuit it is possible to retain positive clearing on the switchboard during the transition period. The provision of battery connected sleeve relays in the cord circuit may necessitate some modifications to the connexions of the bush circuits of incoming junction equipments.

Portable racks of equipment are available to permit the modification of C.B.S.1 multiple

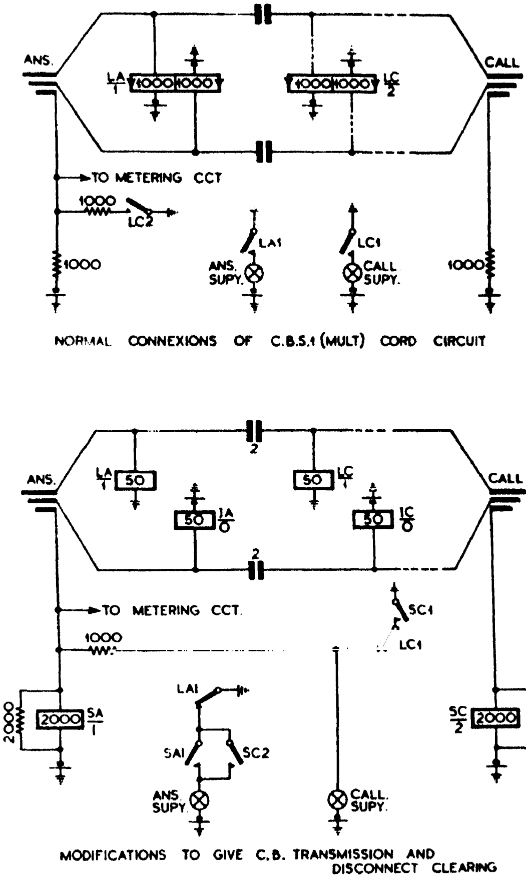


FIG. 760. MODIFICATIONS OF C.B.S.1 (MULT.) CORD CIRCUITS TO PERMIT FITTING OF AUTO INSTRUMENTS PRIOR TO TRANSFER

exchange cord circuits to give central battery transmission whilst still retaining the positive clearing feature (Fig. 760). This equipment includes six relays per cord circuit (4 transmission bridge and 2 sleeve relays) and can be readily applied to most existing exchanges.

The above modifications can be applied only if the existing power supply at the manual exchange is adequate to meet the increased load introduced by the provision of C.B. transmission. If, for this or any other reason, it is not possible to modify

the exchange equipment for C.B. working, then it is necessary to modify or duplicate the apparatus at the subscribers' premises. It has been seen that the normal condition from a C.B.S.1 instrument is an earth on the *A*-line. The first requirement of the changeover arrangements must be to remove this earth from the subscriber's instrument whilst still retaining the earth clearing feature which is necessary for the correct operation of the exchange cord circuits. The new automatic type instrument is connected in parallel with the existing local battery instrument, and the earth connexion to the bell of the latter is removed (Fig. 761). The subscriber can now be rung on the new instrument with the calling signal (the *A*-wire is normally earthed on the subscriber's line jack). When a caller is extended to a cord circuit, current flows from the earth at *IA* over the *A*-wire and through one coil of the supervisory relay, whilst current also flows round the subscriber's loop and through the second coil of the supervisory relay. There is normally not a very great difference in the value of these two currents, and hence the differentially wound supervisory relay (*LA*) does not operate during conversation. When the subscriber replaces his receiver, the disconnexion of the loop at the cradle-switch contacts interrupts the current through one winding of *LA* so that the latter now

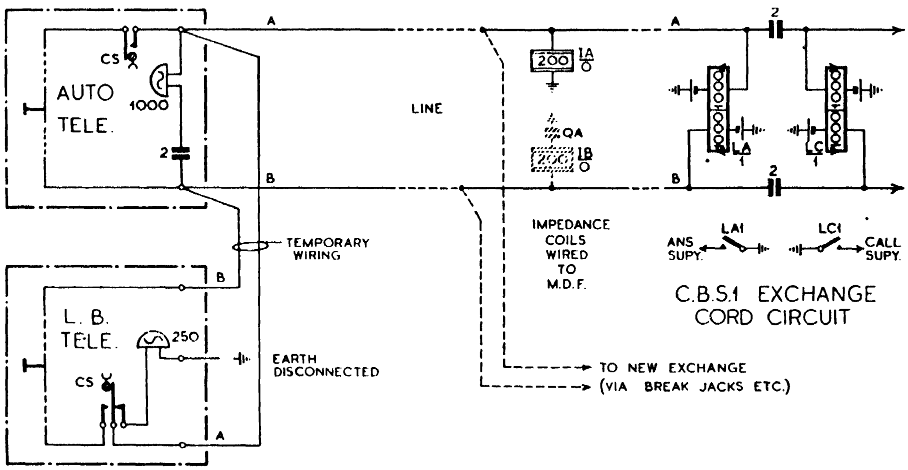


FIG. 761. PROVISION OF IMPEDANCE COILS AT C.B.S.1 EXCHANGE TO PERMIT FITTING OF AUTO INSTRUMENTS

bell over a *loop* ringing circuit from the exchange. (Normally the ringing current is applied to the *A*-wire, and the circuit is completed to earth at the subscriber's bell, but the ringing circuit at the exchange is usually such that the ringing current can be transmitted over a loop circuit without modification of the exchange equipment.) The removal of the earth from the subscriber's bell disconnects the earth clearing circuit, but a disconnexion clearing circuit is provided by the cradle-switch contacts. It is necessary to convert this disconnexion clearing signal from the subscriber's telephone to an earth clearing signal at the exchange, the arrangements being such that, when the lines are changed over to automatic working, any earths are completely removed from the circuits.

The requirements can be met by the provision of an earthed impedance coil (*IA*, Fig. 761) wired to the *A*-wire of each subscriber's circuit on the M.D.F. at the old exchange. This does not interfere operates to the current in the winding connected to the *A*-wire. It is clear that the success of this system depends upon a reasonable balance of currents in the two windings of the supervisory relay during the progress of a call. These two currents cannot, of course, be exactly equal due to the inclusion of the line resistance in one of the circuits. There is a danger that, on long lines, false operation of the supervisory indicator may occur, and before this method is adopted it is necessary to carry out tests to ensure that false operation of the supervisory indicator does not occur under the conditions of maximum line resistance.

There is a further disability of the arrangements shown in Fig. 761. The presence of the impedance coil (*IA*) on the *A*-wire tends to unbalance the impedance of the two speech conductors to earth. In certain circumstances this may result in noise, particularly on junction calls. If trouble is experienced in this direction, it may be necessary to provide a balancing impedance (*IB*) and capacitor.

Fig. 761 shows a new automatic type instrument wired in parallel with the existing local battery installation. As in the C.B.S.2 case, certain of the more modern L.B. instruments can be equipped with a dial, and in these cases it is not usual to duplicate the instruments prior to the transfer. The existing bell circuit is rearranged to include a capacitor (instead of the normal earth connected bell), a dial is fitted, and the installation will work satisfactorily until after the transfer when the instrument can be changed to the correct automatic type.

It should be noted that, if the battery on the *A*-wire coil of the supervisory relay is replaced by earth, the relay will respond to normal disconnexion clearing without further modification. This does not, of course, give central battery transmission, and the normal positive clearing is changed to the less satisfactory negative clearing. Nevertheless, it is a possibility which should not be overlooked for small exchanges where the disadvantages described above may be tolerated

If circumstances prohibit the use of any of the above methods, then the only course is to provide changeover keys at the subscriber's premises and to give the subscriber suitable instructions for the operation of the key at the time of the transfer.

Transfer from Magneto Working. The magneto system makes no provision for direct current signalling between the subscriber and his exchange. There is, therefore, no other course than to provide a duplicate instrument (of the automatic type) at the subscriber's premises and to disconnect the bell in exactly the same way as the method described for conversion from C.B.S.2 exchanges. The wiring arrangements of the subscriber's instrument must, however, be slightly different to prevent the ringing of the auto instrument bell by the operation of the hand generator of the magneto instrument prior to the transfer.

It has already been stated that the normal procedure is to connect the permanent internal wiring of the subscriber's installation direct to the new automatic instrument, and to provide temporary wiring between this instrument and the old manual instrument. This practice must be reversed in a magneto system, i.e. the subscriber's internal wiring must be taken first to the old instrument, and temporary wiring must be run from this point to the new automatic telephone. The connexions at the magneto instrument must be such that the automatic instrument is cut out of circuit when the generator handle is turned. Fig. 762 shows a typical scheme.

Transfer of Coin-box Lines to Automatic Working. The transfer of coin-box circuits to automatic working is somewhat more complex. There is a number of alternative methods which can be used in different circumstances. In cases where the manual exchange is to remain in service after the transfer to automatic working, it is generally preferable to retain the coin-box circuits on the manual exchange until after the transfer. Each coin-box installation is then dealt with individually, and the lines are switched to automatic working when it is convenient to fit the new apparatus. Where the manual exchange is not to remain in service after the changeover, public call offices (and subscribers' coin-box installations) can be transferred to automatic working either (*a*) in

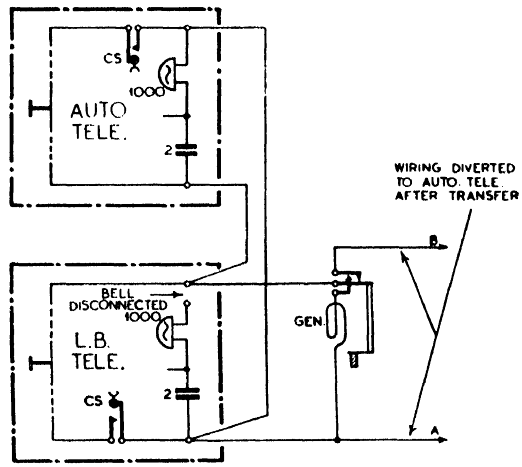


Fig. 762. Method of Connecting New Auto Instrument at Magneto Subscriber's Premises

advance of the main changeover, or (*b*) coincident with the transfer of the ordinary lines.

If it is decided to change over the call offices in advance of the main transfer, it is necessary to ensure that the automatic equipment is in good working order prior to the commencement of the work, and also to open up a limited number of circuits to the automanual switchboard. Circuits must also be provided from the automanual switchboard to the old manual exchange, and sometimes it is desirable to provide a limited service from the automanual switchboard on other junction groups. The call office users are instructed, by means of a suitable notice, to dial "0" for all calls prior to the time of the main transfer. Incoming traffic to the coin-box installation is dealt with by means of a group of circuits between the old exchange and the automanual switchboard.

In director areas, it is sometimes possible to open up a fair proportion of the outgoing routes from

the new automatic exchange prior to the transfer. In such cases it is possible to modify the translation field of a few directors in advance of the transfer so that local traffic is temporarily routed via the tandem exchange to the C.C.I. equipment at the old manual exchange.

If it is not practicable to carry out an advance transfer of the call office lines, the installation should be equipped with the new type of apparatus required for automatic working. A separate bell set is fitted to meet the conditions prior to the conversion, and a changeover key is fitted to switch from the old to the new conditions as soon as possible after the time of the transfer. It is usual to tie the dial of the automatic telephone to prevent mis-operation of the installation during the transition period. Where this method is adopted, arrangements are made for a visit to the call office installation within 15 minutes of the transfer time in order to operate the changeover key and to release the dial. The temporary bell set and changeover key are recovered as soon as convenient. It is clear that with the above scheme it is necessary to staff the old manual exchange for some little time after the main transfer, i.e. until the changeover keys have been operated at all the call offices.

At small exchange transfers, the number of coin-box installations is usually small, and in such circumstances it is common practice to convert all the coin-box installations at the time of transfer. This, of course, puts the call office out of use during the short period required for the actual conversion of the equipment.

Modifications at Outstations. In addition to the arrangements required at subscribers' premises, the conversion of an exchange to automatic working often necessitates some modification of the equipment at other nearby exchanges. In some instances the transfer may necessitate the provision of new junction relay set equipment at the distant centres, and plans must be made for the fitting of this additional equipment concurrently with the installation of the new exchange.

If spare switchboard jacks and spare junction pairs are available, it is sometimes possible to complete the junction work in advance of the main transfer to automatic working. If such spare equipment does not, however, exist it may be necessary to provide a suitable changeover scheme utilizing break jacks or keys which are operated at the time of transfer. (It should be noted that it may be necessary in some cases to provide for the changing over not only of the junction pairs but also of the switchboard circuits to the new relay sets.)

Most automatic exchange transfers are arranged to take place at a time of light traffic. Advantage can sometimes be taken of this to avoid the use of changeover arrangements at the outlying centres. A proportion of the junction circuits (say, one half) are taken out of service about an hour before the transfer time and are modified to meet the new conditions. At the actual time of transfer these circuits are available to carry the traffic until the remainder of the circuits can be similarly modified.

If the new automatic exchange introduces additional subscriber-dialling facilities, it is necessary to examine the multi-metering arrangements at the outlying automatic centres.

Pre-transfer Testing of Lines. To ensure a satisfactory changeover to automatic working, it is the usual practice to carry out rigorous tests of the lines external to the exchange. The subscribers' lines are usually tested for:

(*a*) Insulation resistance.
(*b*) Conductor resistance.
(*c*) Transmission efficiency.
(*d*) Dial speed.

The insulation resistance tests are carried out from the M.D.F. at the new exchange in such a way that all the wiring which will be in circuit immediately after the changeover is included in the tests. The tests are carried out with a 250 V, ohmmeter in conjunction with a "line-reversing" key. The arrangements are such that the insulation resistance of the *A*-wire can be tested whilst the *B*-wire is earthed, and vice versa. An insulation of not less than 1 MΩ is desirable, although, on circuits which are routed through both overhead and underground plant, insulation resistances of down to 250 000 Ω may be allowed. If a high proportion of the line is overhead, and the tests are carried out in wet weather, it is permissible to pass an insulation resistance of 50 000 Ω as an absolute minimum.

The conductor resistance and transmission efficiency tests are required mainly for record purposes, but these tests also serve to indicate whether the lines are within the permissible standards before the new exchange is opened for service.

The dial on every subscriber's instrument must be tested prior to the transfer to ensure that it is in good working order and that the impulsing frequency is within the standard limits (9–11 I.P.S.).

Demonstration of Tones. When any exchange is converted from manual to automatic working, it is important that the subscribers should be given

the opportunity of becoming familiar with the standard tones of the automatic system. Sometimes arrangements are made for the manual subscribers' lines to be connected temporarily to the new automatic exchange before the transfer. By this means, a visiting officer can, by dialling special numbers, demonstrate to the subscriber the significance of the various tones. In other cases it is preferable not to switch the manual subscribers' lines through to the new equipment, but to provide "tone demonstration" jacks on the manual switchboard. These jacks are connected to the new exchange, or to any nearby automatic exchange, so that the tones are continuously available on the demonstration jacks. With such a scheme, the visiting officer requests the manual exchange operator to apply tones to the subscriber's line as required. In very small exchange transfers it is sometimes possible to defer the demonstration of tones until after the transfer to automatic working.

The Transfer. It is usual to select the time for the changeover to automatic working so that the volume of traffic immediately prior to and just after the transfer is small. Some years ago it was the practice to effect the changeover at midnight on a suitable day, but this tends to introduce certain staffing and other difficulties. Modern practice favours the selection of a time during the lunch interval of a mid-week day. At most exchanges the traffic is usually very low about 1 p.m., and a transfer at this time greatly facilitates the post-transfer testing of the lines.

In order to ensure a successful transfer, a detailed plan must be prepared of the timing and sequence of the various operations and of the specific duties of each officer concerned with the transfer. In a large transfer it is usually desirable to have a preliminary practice of the transfer operation, so that each man can become familiar with his duties. The detailed arrangements at any particular exchange depend to a large extent upon the method of changeover (i.e. external teeing, the use of break jacks, etc.). The transfer operation can be broadly divided into three distinct phases:

(1) Some minutes before the time scheduled for the transfer, the telephonists at the old manual exchange request the subscribers to terminate as soon as possible any calls which may be in progress. When the manual switchboard is clear of traffic, the officer in charge at the new automatic exchange is advised accordingly.

(2) At the appropriate time, the officer in charge of the transfer issues instructions to "cut out" the subscribers and junctions from the old equipment. This operation can usually be completed in under 1 minute.

(3) Immediately the "cut out" operation is completed, instructions are given to "cut in" the subscribers, junctions, etc., to the new exchange equipment.

During the "cut in" of the lines to the new exchange, it is necessary to maintain a careful watch for possible congestion on the automatic equipment due to fault or other conditions. If there is serious trouble (which is unusual) it may be necessary to hold up the "cut in" operation.

During the first few hours after the transfer, it is desirable to provide additional staff in the automatic apparatus room to assist subscribers who may be having difficulty with the new automatic system.

Post-transfer Line Testing. It is the standard procedure to carry out simple electrical tests of all lines immediately after their transfer to automatic working. The work of testing a very large number of lines within a short period is facilitated by the provision of special test boxes which are used in conjunction with the test final selectors of the automatic exchange. Fig. 763 shows the arrangements. Usually one test panel per 400 subscribers' lines is provided. The connexions to the panels are terminated on plugs, and temporary jacks are fitted to the test table. These jacks are wired out, either to temporary connexion strips on the final selector racks where they are extended by means of a flexible cord and a plug to the test selector, or, alternatively, the test jacks are wired to the connexion strips of the test selector.

Prior to the day of the transfer, cards are prepared to show the subscribers' lines in final selector bank order, i.e. each card consists of 100 squares arranged as 10 rows each of 10. Entries are made in the squares to indicate the spare lines, the lines temporarily out of service, service lines used in connexion with the transfer, and unidirectional lines. This card is brought right up to date to show the exact conditions on the day of the transfer.

The test panel enables the testing officer to test each line in succession merely by depressing keys which cause the selector to make one rotary step at each operation. The testing procedure is as follows:

(*a*) Key *Z* is depressed to ensure that the test final selector is normal.

(*b*) A key is moved to either the "upper bank" or "lower bank" position to select the particular hundreds group of 200-line final selectors.

(*c*) Key 2 is operated, and the testing officer dials "1" to step the test final selector to the 1st level.

(*d*) Key *R* is depressed once to move the wiper carriage to the first contact of the selected level.

(*e*) If the line is free:

(i) The depression of the "voltmeter" key tests for earth on the *B*-wire.

(ii) The depression of the "voltmeter" and "line reversing" keys tests for earth on the *A*-wire.

(iii) The depression of the "voltmeter" and "earthing" keys, and the momentary operation of the "line reversing" key tests for the presence of capacitor "kick."

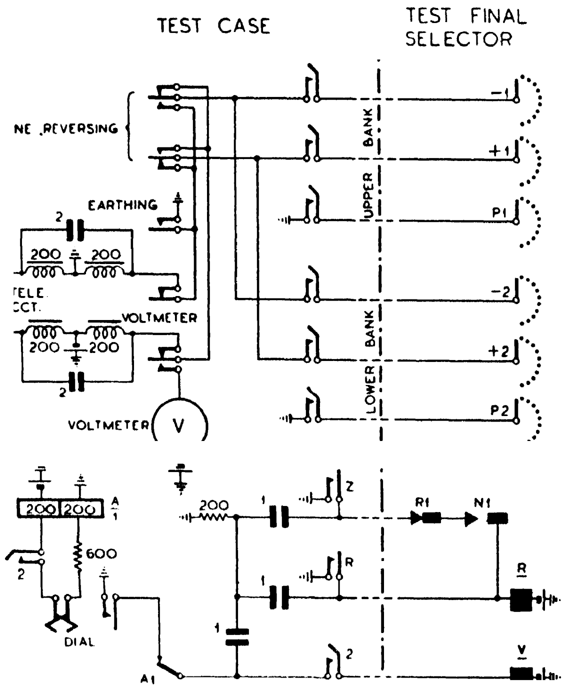


FIG. 763. CIRCUIT OF POST-TRANSFER LINE TESTER

If the test is satisfactory, a $\surd$ is inserted at the appropriate place on the card. Spare lines are tested for the presence of N.U. tone and, if satisfactory, the card is similarly marked.

(*f*) The depression of key *R* causes the test final selector to step to the next line on the level, and the tests are repeated as above.

(*g*) When all lines on the level have been tested, the depression of key *Z* allows the test final selector to restore to normal.

(*h*) The testing officer now dials "2" to step the test final selector to the second level, and the procedure is repeated throughout the whole of the group of lines.

The electrical tests carried out by engineering staff are supplemented by further functional tests by traffic staff. These tests consist primarily of making a test call to the subscriber and by asking the subscriber to dial back in order to verify that the telephone is satisfactory on outgoing calls.

Portable Changed Number Equipment. The opening of a new automatic exchange often necessitates the transfer of subscribers from other adjacent automatic exchanges. Where a large number of such lines is involved, the normal changed number interception equipment is often inadequate to meet the temporary requirements immediately after the transfer. In such circumstances portable changed number equipment is installed. The equipment consists of an apparatus rack, which contains 50 tapping relay sets together with 10 linefinders and their associated relay sets and distributors (see Chapter XXV). The equipment at the automanual exchange consists of 4 double-sided answering panels which are designed for use on a table. In addition a shelf of 10 relay sets is required at the automanual exchange. (This shelf is normally fitted on the main apparatus rack in order to facilitate transport arrangements.) Each panel contains a strip of 10 calling lamps which are multipled on each position, and 10 speaking and flashing keys which are associated with the calling lamps. If the exchange from which the lines are being transferred is to remain in service after the transfer, the apparatus rack is located in the apparatus room of that exchange, but if the exchange is not to remain in service it is usual to locate the changed number interception rack in the exchange to which the lines are being transferred.

Although only 50 tapping relay sets are provided on the apparatus rack, facilities are available for bunching a number of subscribers' lines on each tapping group. The number of lines which may be so bunched depends upon the incoming calling rate of the transferred lines, and is often in the neighbourhood of 6 or 7 lines per relay group. Any subscriber dialling the old number operates the line relay of the relay group to which the number is connected, and this in turn causes a linefinder to extend the caller to an answering equipment at the automanual exchange. The operator then advises the subscriber of the number change.

The connexion of a large number of lines to the changed number equipment coincident with the transfer of the lines to the new exchange would involve the provision of changeover strips and fairly extensive wiring. In order to save the expense of this work, it is usual to connect the

number to N.U. tone within 10 minutes of the time of the transfer. This minimizes the time during which any caller would receive ringing tone. The work of connecting the ceased numbers to the interception equipment is then put in hand, and an endeavour is made to complete the interception facilities within a period of about 2 hours after the transfer.

When a manual exchange is replaced by an automatic exchange, a large number of the original manual exchange numbers is not within the numbering scheme of the new automatic exchange. It is therefore not possible to provide interception facilities for such numbers. A small proportion of the manual exchange numbers may fall within the automatic exchange numbering range, but it is not usual to provide interception equipment and N.U. tone is applied.

EXERCISES XXVI

1. Describe what basic information is required before a start can be made on the engineering design for a new automatic exchange. How is this information obtained?

2. The 1st selectors serving the local subscribers of an automatic exchange are distributed over 24 selector shelves, whilst the 1st selectors serving nearby manual exchanges are distributed over 12 selector shelves. The traffic passing to levels 2 and 3 of the 1st selectors is as follows:

	To level 2	*To level* 3
From automatic exchange subscribers . .	25·5 T.U.	5·8 T.U.
From manual exchanges .	12·7 T.U.	1·9 T.U.

Determine suitable gradings for each of these levels assuming that the traffic from the local subscribers is routed in the same gradings as the traffic from the manual exchanges.

Indicate the groupings of the selector level multiples for each of the gradings, if each rack is fitted with 6 selector shelves designated A, B, . . . F.

The availability of the 1st selector levels should be taken as 10, and the formula $A = 0{\cdot}446N - 1{\cdot}03$ may be used for estimating the number of trunks, N, in a grading, A being the traffic in traffic units. (*C. & G. Telephone Exchange Systems III*, 1948.)

3. Describe in detail the procedure for carrying out a "call-through" test of a new automatic exchange.

4. Explain, with the aid of suitable sketches, how it is possible to provide for the transfer of subscribers' lines from an existing to a new exchange by means of a system of internal teeing. In what circumstances is this method used?

5. What do you understand by the "break jack system" for the transfer of lines to a new exchange? When would it be advantageous to combine this method with the internal teeing scheme?

6. Describe what arrangements you would make at the subscribers' premises and at the manual exchange in readiness for the changeover from a C.B.S.2 manual system to an automatic system. Explain any precautions which must be taken before this scheme is introduced.

7. Discuss the various alternative ways in which it is possible to arrange for the transfer of lines from a C.B.S.1 exchange to a new automatic system. What are the merits and limitations of the alternative schemes?

8. In a certain metropolitan area a 10 000-line manual exchange of the C.B. type is to be replaced by an automatic exchange of similar capacity. In this area there are 300 busy call offices. Describe what plans you would make for dealing with these call offices when the area is converted to automatic working.

9. What tests are made prior to an automatic exchange transfer to ensure that the subscribers' lines and instruments will function correctly after the transfer?

10. Describe, with the help of a suitable diagram, how it is possible to carry out simple electrical tests of all subscribers' lines immediately after their transfer to automatic working.

CHAPTER XXVII

AUTOMATIC AND SEMI-AUTOMATIC POWER PLANTS

ONE of the primary requirements of any modern telephone system is that service shall be available to the subscribers at all times. In the vast majority of exchanges the electrical energy required for signalling, switching, speech transmission, and so on, is derived either directly or indirectly from the public electricity mains. The exchange power supply system must be designed so that continuous and uninterrupted telephone service is available even when the public electricity mains fail. In most manual exchanges and in the earlier automatic exchanges continuity of power supply to the exchange equipment is obtained by the use of large capacity batteries of secondary cells which are charged as required from the mains. In more recent years various schemes have been devised, by means of which it is possible to meet most of the energy requirements of the exchange direct from the public mains, thereby obtaining a material reduction in the initial capital cost of the plant and in the amount of maintenance attention required.

In all cases where the exchange load is met directly from the mains, it is necessary to make provision for an alternative source of supply in the event of a mains failure. The emergency energy may be derived from:

(a) Prime mover generator sets.

(b) Batteries of secondary cells.

(c) A combination of both prime movers and secondary cells.

If a prime mover is the only source of reserve energy, it is very difficult without a costly design to avoid some momentary interruption of service when the mains fail. The difficulty is, of course, due to the problem of arranging for the prime mover to start up and take the load before the voltage from the mains-driven motor generator set falls below the permissible minimum for the exchange. Moreover, all prime movers require periodical maintenance attention or overhaul, and during such periods there is no safeguard against a power supply breakdown. Full security can therefore be obtained only by the provision of two prime mover sets, with the consequent increase in cost.

Secondary cells form a very reliable source of emergency power supply, but the cost of such batteries increases in direct proportion to the time for which emergency cover is required under breakdown conditions. It is the general policy of the British Post Office to guard against short interruptions of the mains power supply by the provision of batteries which have sufficient capacity to run the exchange for a period of, say, 24 hours. If the power failure extends beyond this period, it is necessary to bring into use emergency prime mover generator sets. In the larger exchanges such prime movers are installed as a permanent part of the exchange equipment, but smaller exchanges are catered for by portable engine-generator sets located at strategic centres.

The more simple types of charging equipment, the characteristics of secondary cells, and the less complex exchange power plant schemes are described in Volume I. This chapter, therefore, is devoted to the more common automatic and semi-automatic arrangements.

Charge-discharge Working. Charge-discharge working was the standard method of operating exchange power plants over a number of years. With this scheme two batteries are required, each being alternately charged and discharged. The normal procedure is to discharge each battery substantially through the full range of specific gravity readings. The subsequent recharging is started at the $4\frac{1}{2}$-hour rate, but at a late stage in the charge the current is cut down to the 12-hour rate. The charge is finally terminated when the hydrometer readings indicate an input of 93 per cent of the nominal capacity of the battery. These "ordinary" charges are supplemented by "equalizing" charges at monthly intervals. The procedure for the equalizing charge is similar to that for an ordinary charge, except that the charge is continued until the specific gravity reading of each cell is substantially constant.

This method of working minimizes the waste of energy which always occurs during the final stages of battery charging (due to the conversion of the water of the electrolyte into its constituent gases). The avoidance of vigorous gassing during ordinary charges also reduces the wear and tear of the plates and the frequency at which the cells require "topping up."

Charge-discharge working requires no complex circuits, and the maintenance procedure is simple. Moreover, the system is substantially unaffected by mains failures of normal duration. The load on the battery under mains failure conditions is

usually very little greater than under normal working conditions. On the other hand, this method of working involves frequent cycles of charge and discharge which tend to loosen the active material of the plates. There is also a gradual growth of the positive plates as the underlying lead base is changed to active material. These factors tend to shorten the overall life of the plates.

The size of the cells in a charge-discharge scheme is largely determined by the practicability and economics of the charging arrangements. For example, it is not usually practicable to charge more than one battery during each working day. This means that each battery must be of sufficient capacity to last over a 24-hour period, i.e. the two batteries together provide a reserve of energy sufficient to provide service for 48 hours. If the exchange is not staffed over the week-end, the capacity must be still further increased to provide sufficient reserve for the week-end period. In general, the minimum total battery capacity required under charge-discharge working is several times that which would be required purely to provide an emergency reserve of energy.

Some increase of efficiency can be obtained by the adoption of an "assisted discharge" scheme. With this scheme a suitable rectifier or motor generator set is connected in parallel with the battery to reduce the load on the latter. By this means a smaller battery will suffice and the period between successive charges may be increased. For reasons which will be clear later the amount of assistance which can be given in this way is limited unless some form of voltage control is introduced.

Floating. The most economical method of operating an exchange power plant is to arrange for a generator (or rectifier) to operate in parallel with the battery, so that substantially all of the exchange load is taken from the mains, the full battery capacity being available to carry the load under mains failure conditions. This method is known as *floating* and has several important advantages:

(1) The efficiency of the system is considerably higher due to the virtual elimination of conversion losses. (The watt-hour efficiency of a secondary cell battery is of the order of 70–80 per cent. By supplying the exchange load direct from the motor generator a saving of upwards of 20 per cent in the total energy required is obtainable.)

(2) The capacity of the battery is determined wholly by the amount of reserve required (i.e. the practical requirements of providing a satisfactory charging procedure do not apply).

(3) The elimination of regular cycles of charge-discharge prevents the continual wear and tear of plates which tends to shorten their life.

(4) Gassing is almost eliminated, so that topping up is required only at long intervals.

(5) A considerable amount of maintenance time is saved due to the reduction in the number of records of specific gravity, etc.

If a fully-charged secondary cell is left idle for a prolonged period, there is a gradual loss of charge due to local action resulting from impurities either in the material of the plates or in the electrolyte of the cell. Normally the loss due to local action varies between 1 and 2 per cent per day depending upon the age and general condition of the battery. When a fully-charged battery is floated between the generator and the exchange load, it is necessary to provide some means of making up for the loss of charge due to local action. If, for example, a battery has a capacity of 1000 Ah, and loses 1 per cent of its charge per day, the reserve of energy decreases by 10 Ah during each 24-hour period. This loss can be made up by designing the circuit so that the battery receives a continuous charge of 0·4 A. The provision of facilities for making up the losses due to local action is an important requirement of all float systems.

Voltage Characteristics of Lead-acid Secondary Cells. Before proceeding to a detailed examination of practical float-schemes, it is desirable to review certain of the voltage characteristics of secondary cells of the lead-acid type. When a discharged cell is first placed on charge, the voltage rises rapidly due to the polarization back e.m.f. There is then a steady rise of voltage resulting partly from the increase in density of the electrolyte and partly from the increase in potential of the positive plates. As the charge nears completion the quantity of lead sulphate remaining on the plates is small, and most of the electrical energy is absorbed in decomposing the water of the electrolyte. The final voltage of a cell depends largely on the rate of decomposition, i.e. upon the charging current. Fig. 764 shows the terminal p.d. of a fully-charged cell at different values of charging current. For convenience the current has been expressed in terms of the hourly charging rate. At very high values of charging current, the voltage per cell is of the order of 2·8 V, but as the charging current is reduced the terminal p.d. becomes progressively lower until it reaches a substantially constant value of approximately 2·15 V per cell at very low charging rates.

We have seen in the previous paragraph that the losses due to local action may represent from 1 to 2 per cent of the total battery capacity per

day. To make up a loss of 1 per cent per day it is necessary to apply a continuous charge at the 2500-hour rate. With such a charging current the p.d. at the cell terminals is approximately 2·15 V.

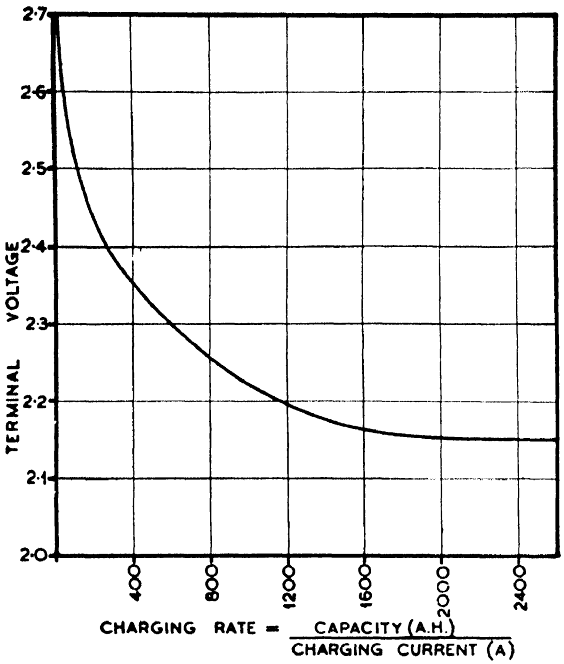


FIG. 764. TERMINAL P.D. OF A FULLY-CHARGED CELL AT DIFFERENT VALUES OF CHARGING RATE

If the loss on a particular battery is 2 per cent, then the charging current must be at the 1250-hour rate, and the resulting voltage at the cell is approximately 2·175 V.

When a fully-charged secondary cell is placed on load, there is a fall in the terminal p.d. as the discharge proceeds. Typical curves are given in Fig. 765. This reduction of voltage is due partly to the decrease in the potential of the plates as the active material is converted to lead sulphate, and partly to an increase in the potential drop in the cell as the electrolyte becomes less dense and of higher resistivity. The potential drop in the cell increases rapidly as the discharge current is increased owing to the concentration of low density electrolyte near the surface of the plates. The time for which a cell can be left in service is determined by the minimum permissible p.d., and, as the p.d. varies considerably with the discharge rate, the period of usefulness is governed largely by the value of the discharge current.

The voltage characteristics of secondary cells have an important influence upon the design of a practical telephone exchange float scheme. Fig. 766 (which is derived from the two previous illustrations) shows the terminal p.d. during charge and discharge of a battery made up of 22, 23, 24, or 25 cells. We have seen that, in order to compensate for local action in a battery, it is necessary to apply a small continuous charge. The minimum charging rate necessary to keep any cell from deteriorating is about the 2500-hour rate. The terminal p.d. of each cell under these conditions is approximately 2·15 V. A 25-cell battery has a terminal p.d. of about 53·75 V under these conditions. The permissible maximum voltage of an automatic exchange is 52 V, and hence it is clear that either

(*a*) the battery must be floated at a lower voltage than that necessary to maintain the cells in good condition, or

(*b*) some means must be introduced for reducing the voltage applied to the exchange busbars.

A 24-cell battery has a terminal p.d. of about 51·5 V when charged at the 2500-hour rate during

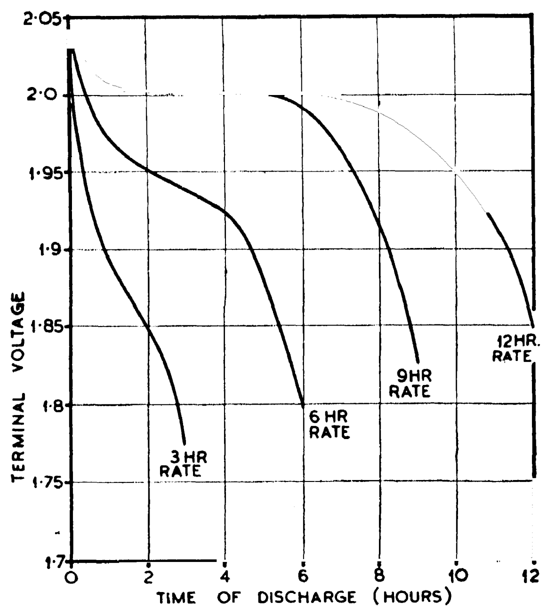


FIG. 765. TERMINAL P.D. OF CELL AT DIFFERENT DISCHARGE RATES

floating. This value is just within the maximum limit (52 V), but there is very little margin. If there is a mains failure during the busy part of the day, the load may be such that the battery discharges at the 6-hour rate (or even at a higher rate). The terminal p.d. of a 24-cell battery

falls to the minimum permissible limit (46 V) in some 4 hours, when it is discharged at the 6-hour rate. Only some two-thirds of the total battery capacity is therefore available to meet an emergency.

A 23-cell battery, when floated at the 2500-hour charging rate, is perhaps the most satisfactory size to ensure that the cells are kept in good condition and that the terminal voltage does not exceed the permissible maximum under ordinary working conditions. (The terminal p.d. of a 23-cell battery at the 2500-hour charging rate is approximately 49·5, i.e. about half-way between the limits of 46 V and 52 V.) Such a battery, however, is of very little value under mains failure conditions since the terminal p.d. very rapidly reaches the permissible minimum of 46 V. At the 6-hour discharge rate, for example, a 23-cell battery will give less than ½ hour's service. A 22-cell battery gives ample margin under floating conditions, but cannot be used without augmentation for carrying the exchange load in the event of a mains failure.

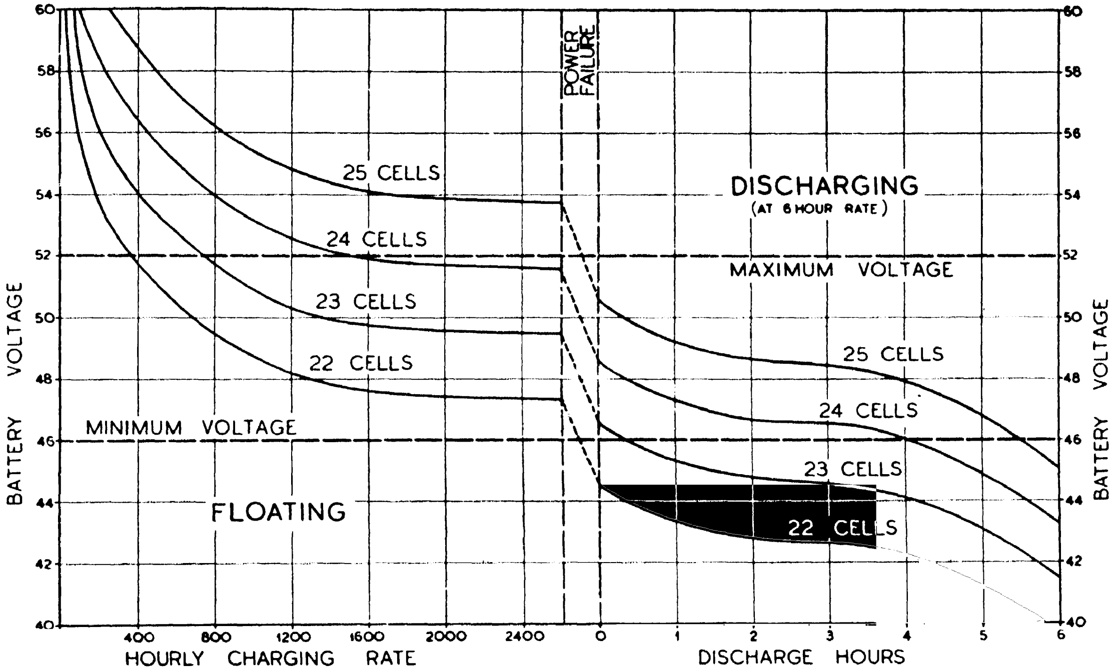


FIG. 766. VOLTAGE CHARACTERISTICS OF BATTERY WITH DIFFERENT NUMBER OF CELLS

Alternative Methods of Floating. There are many alternative forms of float type power plant. These various schemes differ primarily in the arrangements made to maintain the cells in good condition and to ensure that the voltage on the exchange busbars is within the prescribed limits both during floating and during mains failure conditions.

Fig. 767 shows possibly the simplest form of float scheme. It consists essentially of a 24-cell battery which is connected in parallel with a generator set to the exchange busbars. The voltage of the generator is maintained at a substantially constant level by means of some form of automatic voltage regulator controlled by the p.d. of the exchange busbars. In order to maintain the cells in good condition, the minimum float voltage must be 51·5, and the maximum voltage must be limited to 52 in order to meet the requirements of the automatic switching plant. The limitations of this simple scheme are:

(*a*) The necessity of maintaining very close control of the float voltage. This in turn involves the provision of elaborate and expensive voltage regulators.

(*b*) A battery of considerably greater capacity than the daily ampere-hour load of the exchange is necessary in order to provide a 24-hour reserve in the event of mains failure. The exact battery requirements are determined by the maximum anticipated discharge rate of the exchange, i.e. if the discharge rate is heavy a larger battery is required in order to provide the requisite period of cover before the voltage drops to the permissible minimum.

(*c*) Special arrangements are required to recharge the battery if it should become discharged

as a result of a mains failure. At all reasonable charging rates the terminal p.d. of the battery is well above the 52 V maximum, and the battery must therefore be withdrawn from service during the charging process. This in turn means either

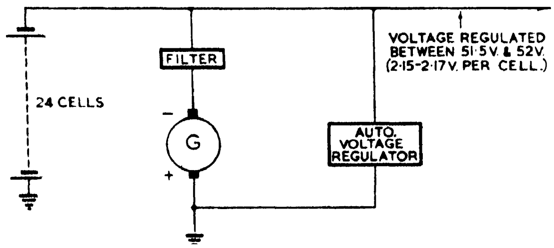


Fig. 767. Simple Float Scheme without Auxiliary Cells

the provision of two sets of batteries, or the exchange must be run direct from the motor generator whilst the battery is being charged in a separate circuit.

Fig. 768 shows a more practicable scheme and is the basis of a number of designs which have been used by various telephone administrations. In this case the main battery consists of 23 cells, and the generator voltage is controlled between the limits of 49·5 V and 50·5 V by means of an automatic voltage regulator. Under these conditions the terminal p.d. of each cell varies from 2·15 V to 2·19 V, which is sufficient to maintain the cells in good condition over a long period. It has been seen that a 23-cell battery provides little or no reserve before the voltage falls below 46 V under discharge conditions. This difficulty is overcome by the provision of an automatic switching circuit which is arranged to insert two or more booster cells in series with the normal battery when there is a mains failure. The conditions are now substantially similar to those with simple charge-discharge working, i.e. the 25-cell, 50 V battery will serve the exchange for an appreciable period before the voltage falls to the minimum of 46 V. The provision of booster cells in this way makes it possible to install a battery of comparable capacity to the daily ampere-hour load of the exchange.

One of the problems with a booster scheme on the lines of Fig. 768 is to provide suitable switching arrangements for the additional cells. The discharge circuit must not, of course, be broken whilst the cells are being inserted, and hence the cells must be short-circuited momentarily during the switching process. The switching operation is, however, comparatively infrequent and suitable circuits can be designed so that the cells do not suffer unduly. Very heavy switch gear is, however, necessary and this adds to the cost and complexity of the arrangements. It is also necessary with this scheme to maintain the booster cells in good condition by the provision of trickle charge or other similar facilities.

The booster scheme also introduces some problems if the main battery becomes discharged as a result of a prolonged mains failure. As in the previous scheme it is not possible to charge up the battery within a reasonable period and still keep the terminal voltage within the maximum permissible limit of 52 V. (This maximum voltage is reached with a 23-cell battery when the charging rate exceeds about the 750-hour rate.) The difficulty can be overcome in a number of ways, e.g. by introducing counter e.m.f. cells in the discharge cells whilst charging is in progress, or by running the exchange on the motor generator set whilst the battery is dissociated for charging.

A somewhat different principle has been used in the design of the float schemes for the larger exchanges in Great Britain. Fig. 769 shows the basic arrangements. Two batteries each of 25 cells are provided, the total combined capacity being sufficient to meet the 24-hour load of the exchange. One battery is held in reserve and is maintained in good condition by a separate trickle charger. The second battery is floated across the generator set at a voltage which is regulated between 50·5 V and 51·75 V. With this arrangement, the terminal p.d. of each cell is between

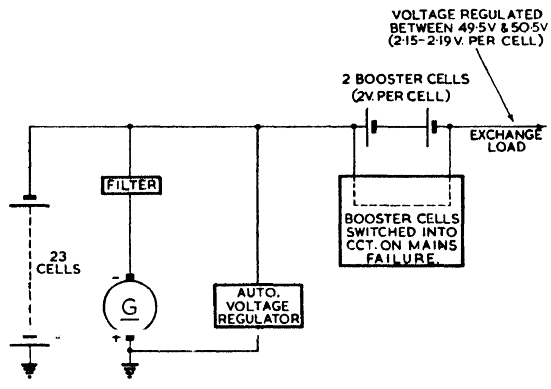


Fig. 768. Float Scheme with Booster Cells

2·02 and 2·07 V. This voltage is insufficient to make up the losses in the battery due to local action, and to provide for this the two batteries are changed over at weekly intervals. The losses in one battery incurred during the previous week's floating are made up during the following week by the trickle charge circuit. This scheme avoids the necessity for booster cells in the event of mains

failure, a full 25-cell battery being available to supply the exchange load. Under such emergency conditions, both batteries can be paralleled in order to provide a 24-hour reserve. The provision of two batteries very considerably simplifies the problem of recharging in the event of the batteries being discharged as a result of a long interruption of the mains supply. Even if both batteries are substantially fully discharged, one battery can be placed "on float" whilst the second battery is being charged at a suitable rate by means of a separate generator. The fully charged battery is then placed on float, whilst the second battery is similarly charged.

In each of the schemes described above, substantially all of the exchange load is drawn from the voltage regulated motor generator set. The current required by an exchange is determined by the general flow of telephone traffic, which in turn varies considerably minute by minute with pronounced peaks in the forenoon and in the afternoon. The float generator must be designed for sufficient output to meet the peak load of the exchange and is therefore worked somewhat inefficiently during the slacker periods of the day. Some increase of efficiency can be obtained by providing several generator sets of different size which can be arranged either singly or in parallel to meet the varying demands of the exchange equipment.

An alternative method would be to design the power plant so that the generator is continuously worked near the full load output. Such conditions can be obtained by providing a generator of a

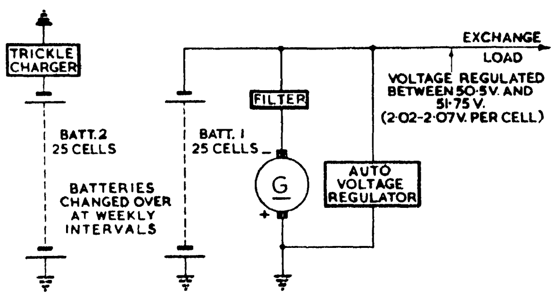


FIG. 769. PRINCIPLE OF DIVIDED BATTERY FLOAT WORKING

capacity approximately equal to the average exchange load current. At times of high traffic density the battery can be allowed to discharge in order to assist the generator in meeting the load. At less busy periods the generator output can meet the exchange load alone, whilst at times when the exchange load is low most of the output of the generator can be used to recharge the battery. The adoption of such a principle does, of course, mean that the terminal p.d. of the battery may vary considerably at various times of the day—if the battery is discharging, the voltage will be slightly below 2 V per cell, whilst if the

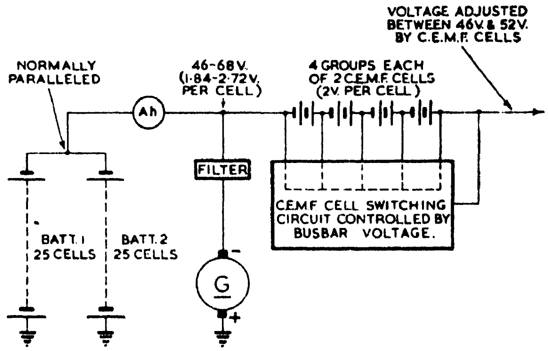


FIG. 770. FULLY AUTOMATIC FLOAT SCHEME WITH VOLTAGE ADJUSTMENT BY C.E.M.F. CELLS

battery is charging at a fairly high rate the voltage may rise to 2·5 V or more per cell. It follows that suitable arrangements must be made to compensate for these changes of voltage by the switching of counter e.m.f. or booster cells in the discharge circuit.

Fig. 770 gives an outline of a typical arrangement. Four groups each of 2 counter e.m.f. cells are inserted in the discharge lead to the exchange busbars. A suitable switching circuit is provided so that the cells can be switched in or out of circuit depending upon the voltage on the exchange busbars. When the exchange load current is high, the battery will discharge and the p.d. on the exchange is slightly less than 50 V when all counter e.m.f. cells are switched out of circuit. As the exchange load decreases part of the generator output is diverted to charge the battery. As the charge proceeds the terminal p.d. of the battery rises and, when the maximum value of 52 V is reached, the switching circuit is arranged to insert one pair of counter e.m.f. cells into the discharge lead. If the counter e.m.f. cells each have a voltage (under working conditions) of 2 V, the insertion of a pair of counter e.m.f. cells reduces the busbar voltage to 48 V. These conditions remain until the continued charging of the battery again raises the busbar voltage to 52 V. The switching circuit now inserts a second set of counter e.m.f. cells to bring the voltage back to 48 V. This process continues until all four groups of counter e.m.f. cells are in use. Assuming that the counter e.m.f. cells each have a terminal

voltage of 2, such a switching scheme permits the battery to attain a peak voltage of 68 V whilst still maintaining the busbar voltage within the maximum limit of 52 V. It thus provides for each cell of the battery to attain a maximum terminal p.d. of 2·72 V—a figure which will cover all normal rates of charge. At some subsequent time an increase in the exchange load causes the battery to discharge and, when the busbar voltage falls to 46, the switching circuit removes one pair of counter e.m.f. cells from the discharge lead. This increases the exchange voltage to 50. As the battery becomes still further discharged, the voltage again gradually drops to 46, at which point a second set of cells is switched out of service. The circuit arrangements are such that a full automatic control of the exchange voltage is maintained throughout all normal cycles of exchange load.

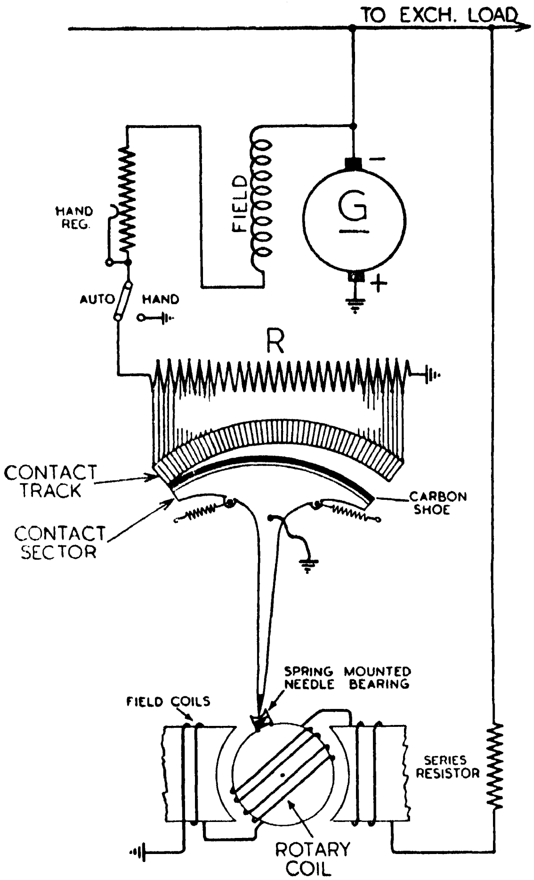


Fig. 771. Principle of Dynamometer Type Voltage Regulator

We have noted that the booster cell switching scheme illustrated in Fig. 768 requires controlling switch gear of heavy construction in order to provide continuity of supply during switching operations. With this scheme the booster cells must have a large capacity since they are required to supply the exchange load under emergency conditions. (They must in fact be of similar capacity to the cells of the main battery.) The conditions with the counter e.m.f. scheme of Fig. 770 are somewhat different in that the c.e.m.f. cells can be of negligible capacity so that they can be short-circuited during the switching operations without harm to the cells.

The counter e.m.f. scheme can be made fully automatic in operation by the provision of an ampere-hour meter or a similar "quantity" indicator in the battery lead. Contacts of this meter can be arranged to cut off the charging plant when the battery is fully charged and to reconnect the power supply at any predetermined degree of discharge. Allowance must be made, of course, in this circuit for the conversion efficiency of the battery.

It is often desirable to provide two batteries of half capacity instead of a single battery. During normal working of the plant the two batteries are connected in parallel and function as a single unit. For economic reasons the charging plant is designed to meet the ordinary day-to-day requirements of the exchange. After a prolonged mains failure, the charging plant may have insufficient capacity to recharge the battery within a reasonable time. Under such circumstances it is advantageous to split the two parallel batteries and to charge one of these from a separate emergency charging plant whilst the second battery carries the exchange load. The parallel battery scheme also permits of renewals and other maintenance operations without the necessity of providing temporary cells to serve the exchange.

Voltage Control. The preceding paragraph has described the broad principles on which a float power scheme can be designed. There are very many variations of these basic principles, but these differences are largely concerned with the methods adopted for the control of voltage. In some cases it is necessary to provide an accurate control of the terminal p.d. of motor generator sets. In other cases the control must be applied to static rectifier equipment. If the scheme employs counter e.m.f. or booster cells, then a suitable circuit must be designed to switch such cells in or out of circuit as required, depending upon the conditions at the exchange busbars.

It is desirable to examine the various methods of obtaining a controlled voltage before proceeding

to descriptions of the detailed float schemes. It is not possible in this volume to describe all the various methods of voltage control which have been successfully used, and the following descriptions are restricted to the more common methods used in the Post Office standard float systems.

Dynamometer Regulators. Fig. 771 shows the principle of operation of an automatic voltage regulator where the control is based upon a dynamometer movement (Brown-Boveri type regulator). The regulator includes a tapped resistor *R* which is wired out to a curved contact track of some 50 insulated segments. A suitably shaped metal sector is fitted with a carbon shoe which is pressed by a suitable spring against the contact track. The lower end of the contact sector is connected via a needle bearing to the rotor of a dynamometer movement. Clockwise rotation of the rotor causes the contact sector to roll over the contact track. The contact sector is connected to earth and therefore short-circuits part of the regulator resistor *R*, depending upon the point of contact with the track. With the sector in its normal position, contact is made with the left-hand extremity of the track, thereby short-circuiting substantially all of the regulator resistor. As the dynamometer rotor moves in a clockwise direction, the point of contact between the sector and the track moves over to the right, thereby inserting an increasing proportion of resistor *R* into the generator field circuit.

The rotor and field coils of the dynamometer movement are connected in series and are wired via a series resistor to a suitable point on the exchange discharge lead. The dynamometer rotor takes up a position which is directly proportional to the current through its coils, i.e. to the p.d. on the exchange busbars. This voltage can be adjusted to the desired value by means of the hand regulator. If, for any reason, the voltage of a generator rises, the increased current through the dynamometer coils causes the rotor to move in a clockwise direction, thereby adding resistance in the field circuit of the generator. The consequent reduction of field current produces a lowering of the generator voltage, thus compensating for the increase. Conversely, any fall in the busbar voltage of the exchange allows the rotor to move back (under coiled spring control) in an anti-clockwise direction to reduce the resistance in the generator field circuit. The increased current now produces a higher generator voltage in order to maintain the required value. Eddy current damping devices (not shown in Fig. 771) are provided to prevent "hunting" of the regulator.

A switch is fitted so that the generator voltage can be placed under automatic control or under hand control, as desired.

This type of dynamometer regulator is rapid in its operation and can be adjusted to give control

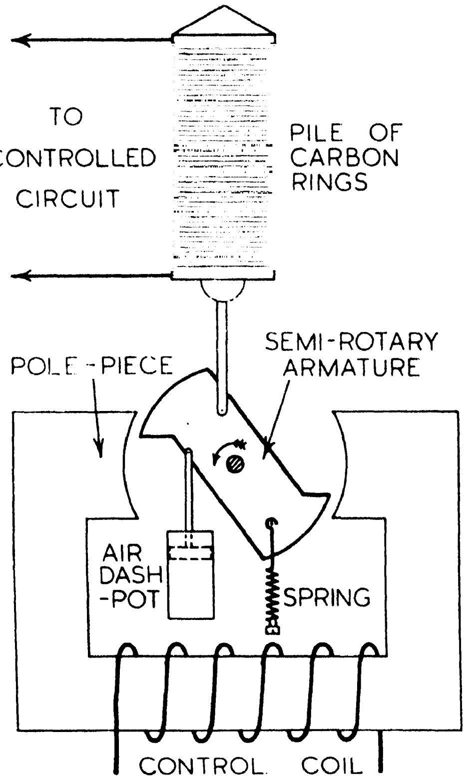


FIG. 772. PRINCIPLE OF CARBON-PILE VOLTAGE REGULATOR

of voltage within very close limits. It is a precision built mechanism and hence is fairly costly.

Carbon-pile Voltage Regulators. Voltage control within fine limits can be obtained by the use of carbon-pile regulators. Such regulators can be used in two distinct ways:

(*a*) By the insertion of an automatically adjusted variable resistance in series with the load, so that the voltage drop in the resistance corrects for variations of supply voltage, or

(*b*) To control the voltage produced by the generators or other source of power supply.

The principle of the carbon-pile regulator manufactured by Messrs. Stone is illustrated in Fig. 772. The main resistance element consists of a pile of carbon rings which are held in compression by an adjustable spring. The free end of the pile is mechanically coupled to an iron rotor which is capable of movement in the field produced

by an electromagnet. When the electromagnet is energized, the tractive force on the armature opposes the force of the main compression spring and results in a decrease of the pressure on the carbon-pile. The resistance of the carbon-pile is

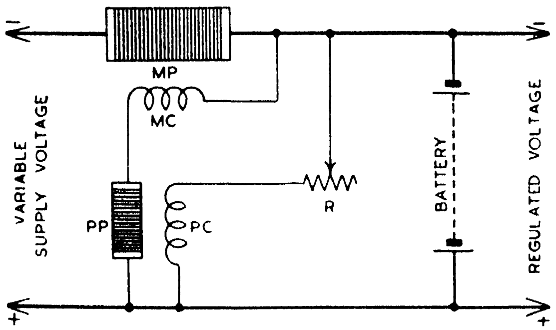


FIG. 773. SERIES TYPE CARBON-PILE VOLTAGE REGULATOR WITH PILOT REGULATOR

largely determined by the contact resistance of adjacent discs. This resistance can be varied over a comparatively wide range by modifying the pressure applied to the pile. The coil of the electromagnet is connected to the controlling circuit in such a way that an increase of voltage increases the tractive force of the electromagnet which, in turn, increases the resistance of the carbon-pile.

Fig. 773 illustrates the use of a carbon-pile regulator in series with the main current supply lead. Series regulators of this type are sometimes required to dissipate a considerable amount of energy in the form of heat, and must be substantially made to handle appreciable power. The increased weight and dimensions of a large regulator tend to decrease the speed of response and the accuracy of regulation. With small regulators of up to approximately 250 W dissipating capacity, a direct-operating mechanism is usually satisfactory, but it is generally preferable to introduce a pilot regulator (as shown in Fig. 773) where heavier currents are to be handled. The coil (*PC*) of the pilot regulator is connected in series with a temperature compensating resistance (*R*) across the supply. The carbon-pile (*PP*) of the pilot regulator is connected in series with the coil (*MC*) of the main regulator across the same control voltage, the carbon-pile of the main regulator (*MP*) being connected between the variable voltage supply and the load. If the voltage of the supply tends to increase, the current through the coil of the pilot regulator also increases in proportion. This in turn decreases the resistance of the carbon-pile of the pilot regulator, and so produces a much greater increase in the current through the coil of the main regulator. The resistance of the carbon-piles of the main regulator is now increased, and the greater potential drop in the main pile reduces the voltage applied to the load. (It should be noted that, whereas the resistance of the main regulator pile is decreased by the passage of a current through the controlling coil, the pilot regulator is arranged to increase its resistance when there is an increase of current through its controlling coil.)

Fig. 774 shows how a carbon-pile regulator can be used to control the output voltage of a motor generator or engine generator set at a telephone exchange. The coil (*C*) of the regulator is connected to the output terminals of the generator, whilst the carbon-pile (*P*) is placed in series with the field coils (*F*) of the machine. If, for any reason, the voltage of the generator tends to rise, then the increased flow of current through the regulator coil produces a corresponding increase in the resistance of the carbon-pile, and a consequent reduction in the value of the generator field current. A reduction in the field current in turn produces a lower terminal p.d. Conversely, if the p.d. of the generator tends to fall, the carbon-pile regulator increases the field current, thereby increasing the output voltage of the machine. In Fig. 774 the carbon-pile is required to carry only the comparatively small field current,

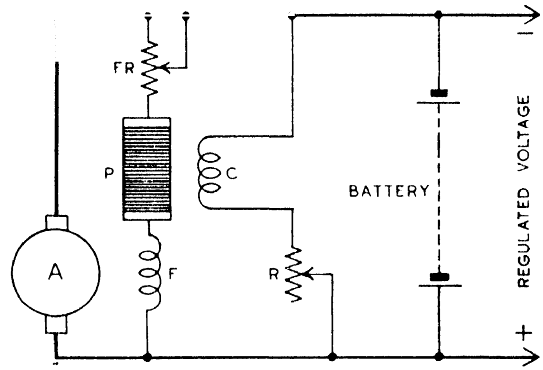


FIG. 774. USE OF CARBON-PILE REGULATOR IN FIELD CIRCUIT OF GENERATOR

and hence a small unit can control the voltage of a high-powered generator.

Fig. 775 gives a general view of a Stone regulator designed for use in the field circuit of a generator. (The cover of the carbon-pile is removed in the illustration.) This particular type of regulator has the semi-rotary control movement illustrated diagrammatically in Fig. 772. It has two carbon-piles, each pile being made up of a number of

annular carbon rings which are held in position by a cage formed by three insulating and heat-resisting rods. The use of annular carbon rings facilitates the dissipation of heat both from the inside and from the outside of the pile. It is usual to fit some

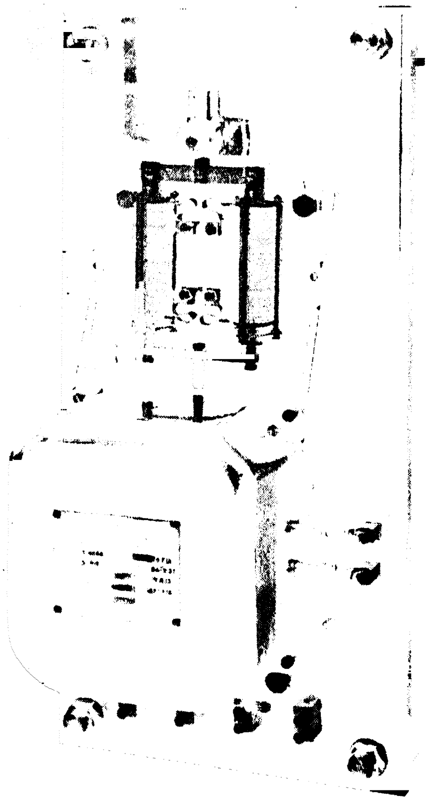


FIG. 775. GENERAL VIEW OF STONE CARBON-PILE REGULATOR
(Top cover removed to show carbon-piles)

means of damping the moving system of the regulator. This damping may either be in the form of a dashpot, where the damping effect is regulated by the air flow from a cylinder through a small hole, or, alternatively, may be effected by arranging that movement of the rotor produces heavy eddy currents in the field system which tend to oppose violent fluctuations.

Isenthal Voltage Regulator. The Isenthal regulator (Figs. 776 and 777) operates on the vibrating contact principle, and the mechanism is so arranged that the make-to-break ratio of a pair of contacts is controlled by the output voltage. A pair of contacts (K) are mounted on flat steel springs with insulating shoes, which rest on the eccentrics (G) on the regulator shaft. The lower springs make contact with a pair of upper springs (H) once per revolution. The two eccentrics are displaced at 180°, and hence the spring sets open alternately as the regulator shaft rotates. The contacts are placed across a field rheostat (A) so that the resistance of this rheostat is cut in and out of circuit as the contacts close and reopen. It is possible to connect the regulator contacts in two ways:

(a) Parallel contact arrangement (as shown in Fig. 776) where the field current to be controlled

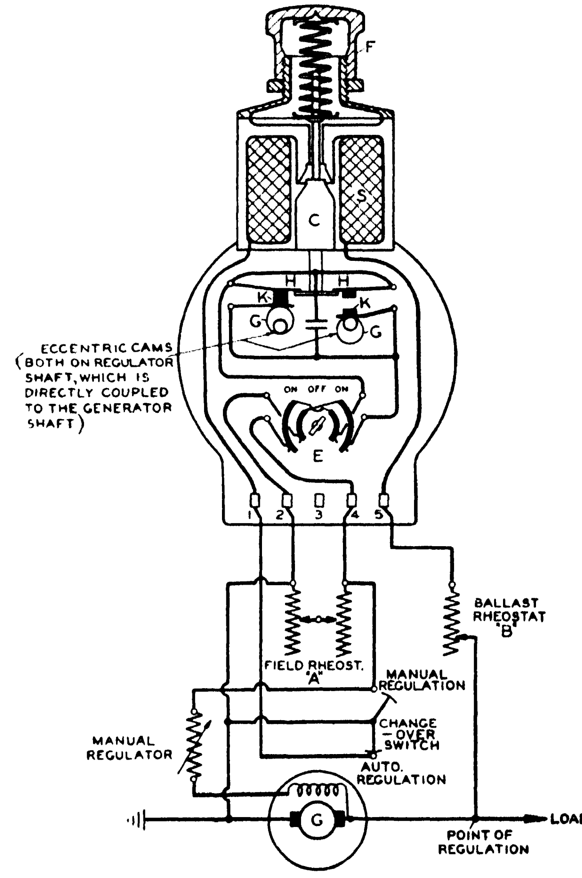


FIG. 776. PRINCIPLE OF ISENTHAL VOLTAGE REGULATOR

does not exceed 2 A. With such connexions, the whole of the field rheostat is short-circuited twice per revolution of the regulator shaft.

(b) Series contact arrangement for use when the generator field current is between 2 and 5 A. The

contacts are so wired that the regulator short-circuits each half of the field rheostat successively during one revolution. By this means it is possible to limit the maximum current passed by the contacts.

The length of the make period of the contacts depends upon the position of contacts *H*, which can be raised or lowered by the core of the control solenoid (*S*). The control solenoid is connected

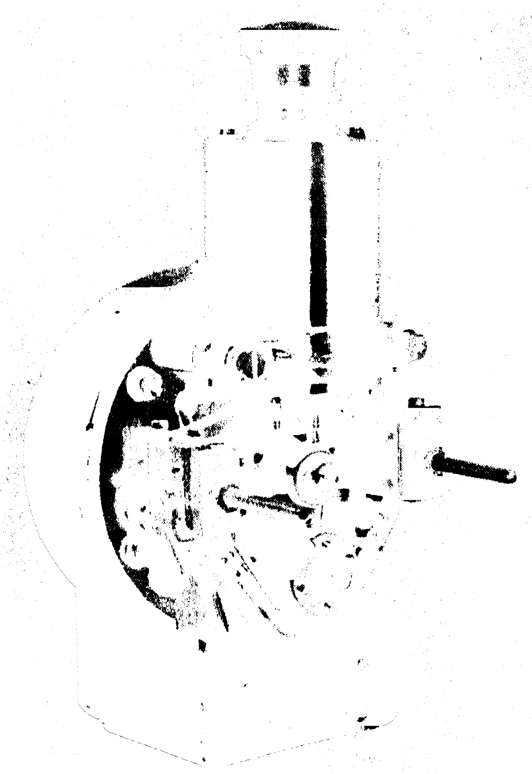


FIG. 777. GENERAL VIEW OF ISENTHAL REGULATOR

across the output terminals of the generator. Thus, any tendency for the generator voltage to rise increases the current through the solenoid, and the core lifts the contacts *H* against the action of the compression spring. The make ratio of the contacts is thereby reduced, and the field current falls, thereby reducing the generator output voltage. If, on the other hand, the generator voltage falls, the current through the solenoid is less and the make ratio of the contacts is increased. This in turn raises the average value of the field current, and so restores the generator voltage to normal.

A commutator switch (*E*) is provided, which enables the polarity of the contacts to be reversed at intervals in order to reduce contact wear. This switch has an "off" position so that the regulator can be cut out of service as required. It is usual to operate this changeover switch daily and, provided the operation is done quickly, there is no noticeable flicker on the supply voltage during the transit period.

The Isenthal regulator is usually driven (either directly or via a belt) from the generator shaft. This is, however, not essential and it can be run from a separate motor if desired. The recommended speed for the regulator is 1300 to 1500 r.p.m. but, in the case of small generators (up to 2 kW), the speed may be as high as 2500 r.p.m. Speeds as low as 1000 r.p.m. are often satisfactory.

When the regulators are applied to mains-driven motor generators, it is possible to obtain an output voltage which remains constant within ± 1 per cent of the nominal value. (When the series contact arrangement is employed, $\pm 1\frac{1}{2}$ per cent is obtainable.) These limits can be maintained when the input voltage to the driving motor varies by ± 10 per cent or, in a.c. cases, where the supply frequency varies by ± 5 per cent of the nominal value. The Isenthal regulator can also be fitted to prime mover generator sets or can be used for controlling the output voltage of an a.c. generator by energizing the control coil through a potential transformer and rectifier equipment.

Drum-switch Regulator. Another form of voltage regulator is based upon the use of a drum switch of a type which has been used extensively for many years on electric traction control gear. Fig. 778 gives a general view of a switch mechanism manufactured by Messrs. E. N. Bray, Ltd. The switch is very substantially built with radial contact arms fixed to a centre rotatable shaft. This shaft is fitted with a ratchet at each end, and is moved in the required direction by the energization of one or other of the two solenoids which engage with the ratchets. The shaft can be rotated by this means through an angle of about 150° to vary the output of a generator between no load and full conditions.

A typical control element is given in Fig. 779. The field regulator of the generator is wired to the fixed contact studs of the rotary switch, the connexions being such that part of the field resistance can be short-circuited by the position of the contact arm. The mechanism is controlled from a contact voltmeter connected to a suitable point on the exchange discharge lead. This voltmeter has two contacts set at the upper and lower

limits between which regulation is required. If at any time the busbar voltage rises to the upper limit, the operation of the voltmeter contacts

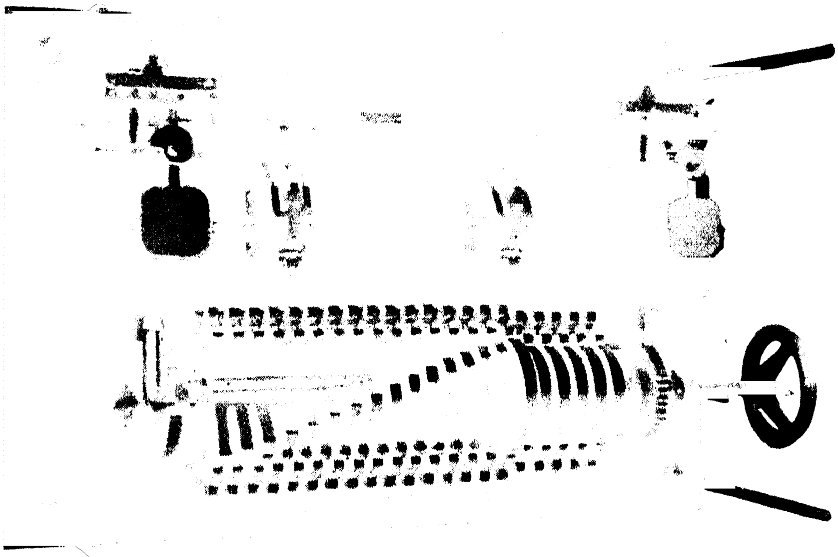


FIG. 778. GENERAL ARRANGEMENTS OF DRUM-SWITCH REGULATOR
(*Messrs. E. N. Bray, Ltd.*)

energizes relay *VH* which locks via ***VH*1** to the common earth. ***VH*2** completes a circuit for the relief relay *HR*, and ***HR*1** in turn energizes the solenoid *B* of the rotary switch. This moves the contact arm one step in a clockwise direction, thereby removing the short circuit from a portion of the field regulator resistance. The decrease of field current reduces the output voltage of the generator, thereby bringing the busbar voltage down below the maximum limit. If, on the other hand, the exchange voltage falls to the lower limit, contact *V*1 moves in the opposite direction to operate relay *VL*. ***VL*1** provides a locking circuit, whilst ***VL*2** energizes the relief relay *LR*. ***LR*1** now energizes the second solenoid *A* to move the rotary switch one step in the opposite direction, i.e. to decrease the field resistance and hence to increase the generator voltage.

The solenoids of the mechanism are provided with contacts *A*1 and *B*1. These contacts open when the armature of the solenoid is operated, and remain open (under the control of a delay mechanism of the escapement type) for a period of some 2 sec after the solenoid armature is released. Thus under, say, a high voltage condition, earth is extended via *A*1, *B*1, and ***V*1** to operate relay *VH*. *VH* in turn operates relay *HR*, and *HR* energizes solenoid *B*. Contacts ***B*1** now open to release relays *VH* and *HR* and thus to de-energize solenoid *B*. Contact ***B*1**, however, remains open for a short period after the release of *B* in order to isolate *VH* and *HR* until such time as the busbar voltage has had time to respond to the changed conditions. If this delay were not

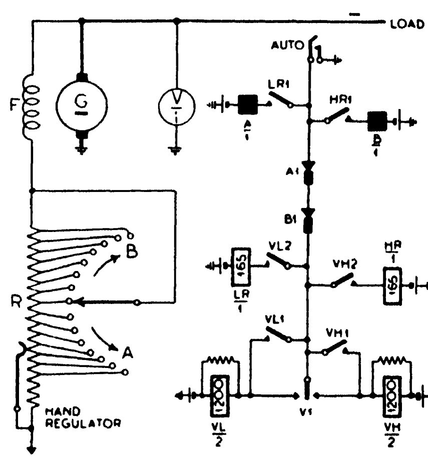


FIG. 779. METHOD OF CONTROLLING VOLTAGE BY DRUM-SWITCH

provided, there would be a danger of relay *VH* re-operating before the *V*1 contact has time to move from the high voltage position. In this latter connexion, it should be noted that the circuit

arrangements are such that the voltmeter contact ($V1$) never breaks a relay circuit. The initial current when $V1$ makes is very small due to the inductance of the relay winding, and once the relay has operated a hold circuit is provided via $VH1$. This arrangement is necessary to avoid arcing and the consequent deterioration of the delicate voltmeter contacts.

It is possible by means of this regulator switch to maintain the p.d. on the exchange busbars within 1 V. It should be noted, however, that unlike some of the schemes already described, there is some delay in the regulating action. It has been found in practice that this delay is no material disadvantage due to the buffer effect of the floating battery. This battery is, of course, slightly discharged during periods of increasing load and recharged to some extent when the load is falling. The extent of these charge and discharge periods can be reduced by reducing the difference between the upper and lower voltage settings. Too close adjustments are, however, undesirable owing to the frequent operation of the regulator and the consequent tendency to instability.

One of the advantages of the drum type regulator is that it can be connected to the normal field regulator of an existing generator set. The switch is therefore particularly suitable for converting existing charge-discharge power plants to float working. The equipment is particularly robust, is comparatively cheap, and has low maintenance charges. Moreover, since the control consists of short pulses of current through the solenoids, there is no continuous drain on the power supply system.

Control of Rectifier Output. In the smaller exchanges it is often more economical to provide static rectifiers instead of motor generator sets. For very light demands rectifiers of the "dry plate" type may be used, whilst for somewhat larger installations mercury arc rectifiers are often employed. Usually the power plant at these small exchanges is of the full automatic type where voltage control is provided by counter e.m.f. cells in the discharge lead. Under these conditions it is not necessary to provide close voltage control of the rectifier output.

It is interesting to note, however, that there is a number of float schemes in use at telephone repeater stations and at telegraph centres which depend upon regulation of the output from static rectifiers to maintain the voltage at the required level. Such control of voltage is usually obtained by providing a tapped input winding to the mains transformer and by adjusting the tapping point to increase or decrease the output from the rectifier unit. In some cases the tap changing switch is operated by a small electric motor which is placed under the control of a contact voltmeter. In other schemes control is obtained from a suitable dynamometer movement.

Counter E.M.F. Cells. The counter e.m.f. cells used at all except the very small exchanges are of a type specially designed for the purpose. These cells consist of nickel-plated iron electrodes immersed in a solution of caustic potash (potassium hydroxide). When a direct current is passed through the cell, hydrogen is released at the cathode and oxygen at the anode. The nickel plating of the electrodes is inert chemically to these gases, and hence no chemical reactions occur due to the passage of current. The gases very quickly form a molecular film over the surface of the electrodes so that during operation the unit behaves as an electrolytic cell with electrodes of oxygen and hydrogen.

The construction of the cell and its characteristics have been described in Volume I. Under normal working conditions the back e.m.f. obtainable is of the order of 2 V per cell and (over a reasonable range) this back e.m.f. is fairly constant. (It varies from about 1·95 V to 2·1 V when the current varies from 50 per cent to 150 per cent of the normal rating.) The chief advantage of the nickel counter e.m.f. cell lies in the absence of stored energy which makes it possible to short-circuit the cell with impunity during switching operations. When a cell is re-introduced into the discharge lead, the back e.m.f. rises to about 1·5 V in 2 or 3 sec from the removal of the short circuit. Within a minute the voltage attains a stable value of 1·9 to 2 V.

The nickel type of counter e.m.f. cell is unsuitable for use at very small exchanges where the discharge current may fall to a very low value at various times of the day. When the current through such a cell falls to a small fraction of the rated current, the back e.m.f. falls rapidly (see Volume I). The use of such cells would therefore cause large fluctuations in the voltage applied to the exchange busbars under conditions of light load. In such circumstances it is the usual practice to install counter e.m.f. cells of the normal lead-acid type. These cells are charged by the exchange load current, and the stored energy may cause momentary circulating currents of a fairly high value if the cells are temporarily short-circuited during the switching operations. Their use is, however, restricted to power plants of very small size, and it is usually possible to provide for such circulatory currents without the use of unduly heavy and expensive switch gear. The back e.m.f.

obtainable per cell depends upon the relation between the load current and the capacity of the cell. Under normal working conditions the back e.m.f. is approximately 2·5 V per cell.

Mercury Switches. Switches with mercury tube contact units are a common feature of many types of float power scheme. In the smaller types of power plant, mercury switches can be used for switching counter e.m.f. cells into the discharge lead, whilst similar switches are often used for controlling the electromagnets of heavy contactors and similar mechanisms.

The contact tubes of mercury switches can be designed to give a wide range of operating and release lags, simple changeover actions, make-before-break combinations, and so on. Fig. 780

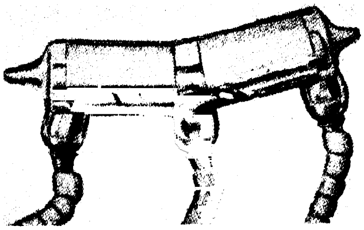


FIG. 780. MERCURY TUBE WITH SIMPLE CHANGEOVER CONTACT ACTION

shows a small mercury tube with a simple changeover contact action. Contact between the centre electrode and either of the two end electrodes can be made by tilting the tube in the required direction. Fig. 781 shows a mercury tube designed to provide a time delay on operation and on release. Such a tube can be made to give a reliable delay of the order of 10 sec or more. The delay feature is obtained by the provision of a narrow capillary tube between the two compartments. The time delay is determined by the rate of flow of the mercury through this narrow orifice.

Fig. 782 shows another design of mercury tube which provides a long time delay before contact is broken but a quick remake of the contacts when the tube is restored to its normal position. The two compartments of the tube are connected together at the lower side by means of a narrow capillary tube. When the tube is tilted in an anticlockwise direction, mercury flows through this narrow tube and, after a time delay, the mercury leaves the upper of the two electrodes. When the tube is now restored, the mercury pours quickly through the spout from the left- to the right-hand compartment, thereby quickly re-establishing the circuit between the two electrodes. This same tube can, of course, be used to give a quick make and slow break by modifying the method of mounting.

Mercury tubes are usually filled with an inert gas at low pressure, and it is common practice to provide porcelain liners (which are fused to the glass envelope) on tubes of the simpler types. Small tubes of the type illustrated will carry up to 20 A

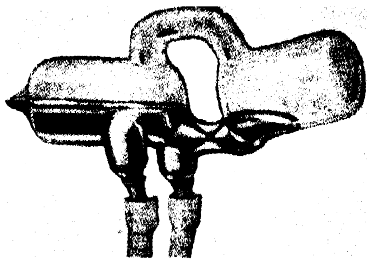


FIG. 781. MERCURY TUBE DESIGNED TO GIVE SLOW OPERATE AND SLOW RELEASE ACTION

non-inductive load at a pressure of 250 V. Tubes of a larger design, which will carry up to 40 A, are also available. The tubes can be safely used on inductive circuits, but generally speaking any tube used in such circumstances should be capable of breaking a current higher than the normal circuit current. It is also desirable to provide a spark quench circuit when mercury contacts are required to break a highly inductive circuit.

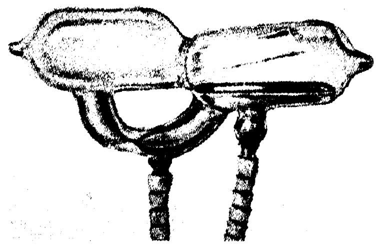


FIG. 782. MERCURY TUBE TO GIVE SLOW BREAK AND QUICK REMAKE

Fig. 783 gives a part section of a typical mercury switch. The tubes are mounted on a tilting platform which is provided with spring loaded latches at either end to hold it in the operated or in the unoperated position. Two solenoids are mounted below the platform and when either is energized it raises a loose iron core, which engages with a plunger to release the latch and to throw the platform into its other position. Once operated, the platform automatically latches until it is

released by the second solenoid. It should be noted that switches of this type require only a short pulse of current to change over the position of the mercury tube platform.

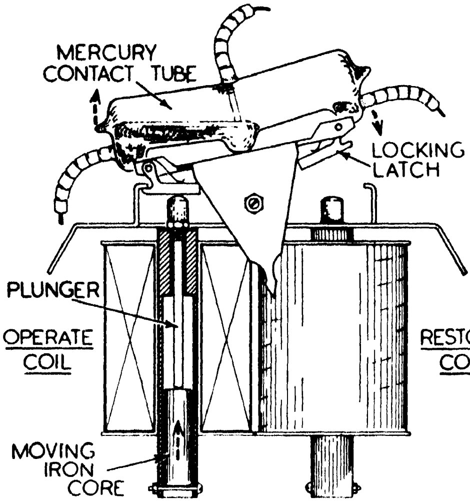


FIG. 783. PART CROSS-SECTION OF TYPICAL MERCURY SWITCH

Switches of similar design are also available with a non-locking action. Such switches have only one operating solenoid but are provided with a spring so that the platform is restored to normal immediately the solenoid is de-energized.

solenoids, i.e. an operate coil which, when energized, short-circuits the counter e.m.f. cells, and a trip coil, the operation of which removes the short circuit from the group of cells. If the voltage on the main discharge lead rises above the permissible maximum (52 V in this case) the closure of the voltmeter contacts operates relay *H*. *H*1 provides a holding circuit for relay *H* independent of the voltmeter contacts, whilst *H*2 energizes a heavy-duty relief relay *MH*. This latter relay is provided with two mercury tubes, a make contact *MH*1, and a break contact *MH*2. The *MH*2 mercury tube is of a special design so that the connexion is not broken until some 2·5 sec after the switch has operated. The contacts do not remake until after a similar period when the switch restores (see Fig. 781). Tube *MH*1 is the normal quick-make quick-break type.

Let it be assumed that, when the high voltage condition occurs, all the counter e.m.f. cells are out of circuit, i.e. they are all short-circuited by their respective contactors. The operation of *MH*1 completes a circuit for the trip coil of the contactor associated with group 1 of the counter e.m.f. cells. The energization of this trip coil operates the contactor latch, thereby allowing the main contacts to open and remove the short circuit from the cells. Some 2·5 sec after the closure of *MH*1, contact *MH*2 breaks the circuit for relays *H* and *MH*. *MH*1 now restores to de-energize the trip coil of contactor 1. The slow restoring

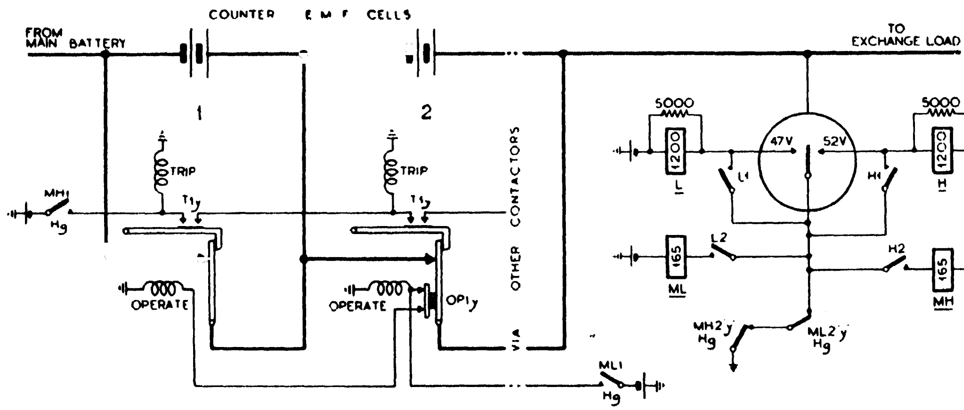


FIG. 784. METHOD OF SWITCHING C.E.M.F. CELLS BY LATCHING CONTACTORS UNDER THE CONTROL OF A CONTACT VOLTMETER

Switching of C.E.M.F. Cells by Contactors. Fig. 784 shows a typical method of switching nickel type counter e.m.f. cells by means of contactor mechanisms. In this example the counter e.m.f. cells are arranged in groups of two and each pair of cells is normally short-circuited by a separate contactor. Each contactor is provided with two feature of the *MH*2 tube maintains the disconnexion for a further 2·5 sec in order to prevent re-operation of relay *H* before the back e.m.f. of the counter e.m.f. cells has had time to reduce the voltage on the exchange busbars. The trip armature of the contactor is provided with a pair of contacts (*T*1) which make some 10 sec after the

contactor has been tripped. After this delay period, the contacts close and the trip circuit is extended to the second contactor. This delay is, of course, necessary to ensure that the second trip coil is not energized from the initial operation of ***MH*1**, and also to prevent the operation of a second contactor before the conditions have settled down from the first switching operation.

If the battery voltage continues to rise, the contact voltmeter again operates when the p.d. reaches 52 V. Relays *H* and *MH* are energized as before, and contact ***MH*1** now energizes the trip coil of contactor 2. (It will be noted that the trip coil of contactor 1 is also operated under these conditions, but this is of no consequence since the first contactor has already been tripped at the previous operation.) The second group of counter e.m.f. cells is now switched into circuit and, after a period of a few seconds, the build-up of back e.m.f. reduces the busbar voltage. If (as is usual) there are more than two groups of counter e.m.f. cells, the switching procedure continues in this manner to insert more and more counter e.m.f. cells.

If the battery voltage commences to fall to such an extent that the voltmeter makes contact on its lower limit, relay *L* is operated. *L*1 provides a hold circuit which is independent of the voltmeter contacts, and ***L*2** operates relay *ML*. As in the case of relay *MH*, there are two mercury contact tubes on relay *ML*. ***ML*1** is of the quick acting type, whilst ***ML*2** has the 2·5 sec delay feature already described. The operation of ***ML*1** energizes the operate coil of the last tripped contactor of the series (say, No. 2) thereby short-circuiting one group of counter e.m.f. cells. Auxiliary contacts (***OP*1**) are provided on the operate armature to extend the operate lead to the preceding contactor. As in the case of the trip coil contacts, these auxiliary contacts are provided with a mechanical delay of some 10 sec to prevent irregular operation of the preceding contactors. If, after the delay period of 10 sec, a further low voltage condition occurs, the re-operation of *L* and *ML* re-operates contactor No. 1 to exclude a further group of counter e.m.f. cells from the discharge circuit. As will be seen later, the complete circuit provides a number of additional features to guard against failure of the contact voltmeter or of the contactors.

Control of Counter E.M.F. Cells by Motor-switch. A c.e.m.f. cell switching scheme using latching contactors requires fairly complex timing gear to prevent false contactor operation. An alternative method of control is to utilize a motor-driven selector switch. Fig. 785 shows such a unit which has been designed (Messrs. Bray) specially for switching four groups of counter e.m.f. cells into the discharge circuit as required. The contacts of the switch are arranged in a straight line, and the required switching operations are set up by moving a brush assembly to the appropriate position over the line of contacts. The brush assembly is mounted on a block with internal thread, and is moved to the required position by the rotation of a square threaded shaft. The driving power is obtained from a small reversible motor via a suitable reduction gear. The design is such that the contact brush makes

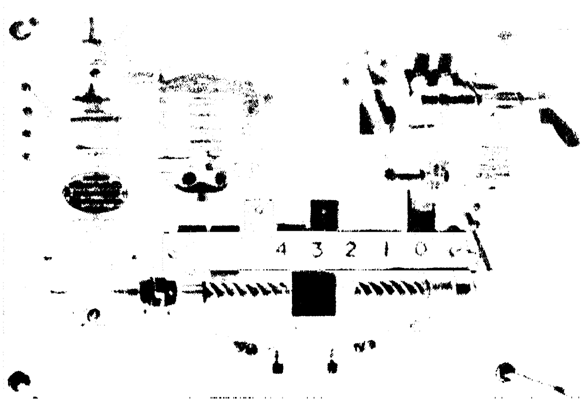


Fig. 785. General View of Motor-switch (Cover Removed)

one complete step for one revolution of the threaded shaft (approximately 3 sec). Auxiliary contacts are provided at either end of the mechanism to prevent over-drive. The motor-switch is less costly than a contactor scheme which gives the same facilities, requires less mounting space, and the associated control circuits are simpler.

Fig. 786 shows a typical application of the motor-switch. In this particular case the float scheme requires four groups each of 2 counter e.m.f. cells with facilities for switching one, two, three, or four groups of cells into the discharge circuit depending upon the voltage at the exchange busbars. For purposes of description let it be assumed that two groups of counter e.m.f. cells are in circuit (i.e. the brush of the switch is resting on contact No. 2). If the voltage rises to such an extent that the voltmeter makes contact at its upper limit, relay *H* operates from the earth at *MS*4. ***H*1** provides a locking circuit independent of ***V*1**, whilst ***H*2** energizes the relief relay *HR*. ***HR*1** now completes the circuit for the driving motor of the switch via field winding No. 2. A braking magnet (*BM*) is in series with this circuit, and the current passing through the motor

operates the armature of the braking magnet to free the operating shaft of the switch. The direction of the field winding ($F2$) is such that rotation of the motor armature moves the brush gear to the left. Contact ***MS*4** operates only whilst the brush gear is moving between consecutive contact segments. As soon as the brush gear commences to move, therefore, a circuit is provided for holding relay *HR* via ***HR*2** and ***MS*4**. The circuit is maintained until the brush gear is centrally positioned on segment No. 3. This feature is necessary to prevent the brush gear from coming to rest between contact segments. By the time contact *MS*4 restores (i.e. when the brush gear is centrally located on contact No. 3) the *C* group of counter e.m.f. cells has had time to build up its voltage and to reduce the busbar p.d. If the voltage should again rise to the upper limit, relays *H* and *HR* are again operated and the switch makes one further step (i.e. to position 4) to include the fourth group of counter e.m.f. cells.

When the voltage on the exchange decreases to the lower limit, contact ***V*1** operates relay *L*, and ***L*2** operates relay *LR*. ***LR*1** now completes a circuit for the switch driving motor via the second field winding *F*1. This winding is opposite in direction to *F*2 and causes the motor to rotate in the reverse direction. The brush gear is thus moved to the right, and the sequence of operations is similar to that already described. Contacts ***MS*2** and ***MS*3** operate when the contact brush moves to the two extreme positions of the switch. By disconnecting the operate circuit of relay *LR* or relay *HR*, these contacts prevent any further movement.

Switching of C.E.M.F. Cells by Mercury Contact Relays. We have seen that the nickel-alkaline type of counter e.m.f. cell is unsuitable for use at small exchanges where the discharge current may be very low. (The back e.m.f. of this type of cell decreases rapidly when the current falls to a small fraction of the normal current.) A lead-acid type of counter e.m.f. cell must therefore be used in such circumstances, and the stored energy in such cells makes it impossible to adopt a simple short-circuiting switching scheme. In the absence of facilities for short-circuiting the cells, a make-before-break switching action is required to maintain continuity of supply to the exchange equipment.

If the maximum discharge current is comparatively small (say, under 20 A) the switching operations can be effected by mercury tube switches. The make-before-break contact tubes must, of course, be capable of carrying the circulating current from the counter e.m.f. cells during the short time for which the cells are short-circuited. With the small type of counter e.m.f. cells used on such plants, it is possible to limit this short-circuit current to about 40 A during the bunching period of the contacts by the insertion of low value limiting resistors which do not materially affect the discharge circuit.

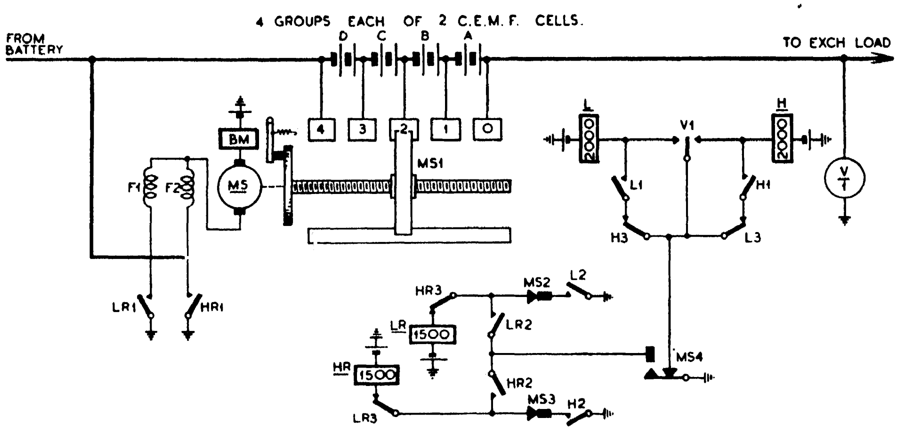


FIG. 786. SWITCHING OF C.E.M.F. CELLS BY MEANS OF MOTOR-SWITCH

Fig. 787 shows a typical switching scheme utilizing mercury tube switches of the type previously illustrated. There are two such switches (*C* and *D*) each of which controls a group of two lead-acid counter e.m.f. cells. If a "high volts" condition exists, the closure of contact ***V*1** operates relay *H* to the battery at *C*2. ***H*2** provides a holding circuit for *H* independent of ***V*1** whilst ***H*1** energizes the relief relay *HH*. Contact ***HH*1** now completes a circuit for the operate solenoid of mercury switch *C*. The make-before-break tube of this relay (***C*1**) cuts in the first group of counter e.m.f.

cells. The 0·1 Ω resistor limits the circulatory current during the bunching period of the contacts and remains as a series impedance in the main discharge lead. Contact **C2** disconnects the battery potential from relays *H* and *HH* so that both relays restore. Tube **C3** is of a special type (Fig. 781) designed to give an operate lag of the order of 5–10 sec. After this delay period, **C3** closes to reconnect the common battery to the various relays and solenoids. Contact **C4** disconnects the current through the operating solenoid of relay *C* and prepares the circuit for the operation of relay *D*. During the slow operate period of contact **C3**, the back e.m.f. of the counter e.m.f. cells builds up and thereby reduces the busbar p.d. If a further voltage rise towards the upper limit occurs, the next operation of relays *H* and *HH* causes relay *D* to operate, and **D1** switches the second group of counter e.m.f. cells into the main discharge lead. (It will be noted that the 0·1 Ω resistor is now no longer in the discharge circuit.) After a delay period contact **D3** operates to disconnect the holding circuit for relays *H* and *HH*, whilst **D2** supplies a replacing battery in readiness for a subsequent operation of relays *L* and *LL*. **D4** prepares for the restoration of relay switch *D* at a later stage.

If the voltage on the exchange busbars now decreases to the lower limit of the contact voltmeter, relays *L* and *LL* operate in a manner substantially similar to that already described for relays *H* and *HH*. **LL1** energizes the restoring solenoid of relay switch *D*, and **D1** removes one pair of counter e.m.f. cells from the discharge circuit. (The 0·1 Ω resistor again limits the circulatory current during the bunching time of the contacts.) **D2** disconnects the holding circuit for relays *L* and *LL*, and **D4** changes over in readiness for the restoration of the *C* switch at a later stage. After a delay period (5 to 10 sec) **D3** remakes in order to restore the battery condition to the controlling relays and switches. The same process continues if there is a further fall in the busbar voltage. The operation of relays *L* and *LL* now energizes the restore coil of relay switch *C* to exclude the remaining pair of counter e.m.f. cells from the main circuit.

Use of Rotary Switch with Rectifier. When lead-acid type counter e.m.f. cells are used in a float system, one of the main problems is to design switch gear which will satisfactorily carry the comparatively heavy momentary currents during the short time when the counter e.m.f. cells are short-circuited. Unless arrangements can be made to prevent the circulatory current, it is necessary to employ either mercury switches or fast operating contactors. Mercury switches are fairly expensive and must be carefully designed to ensure reliable operation. A system of high-speed contactors is also expensive for power plants of small capacity.

Fig. 788 shows an interesting switching scheme utilizing a slow operating rotary selector switch in conjunction with a dry-plate rectifier unit. There are two arcs to the switch and the brushes of these

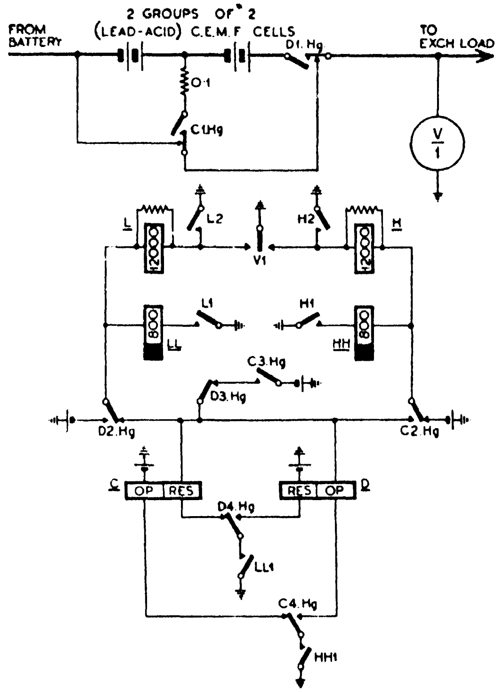


FIG. 787. SWITCHING OF LEAD-ACID TYPE C.E.M.F. CELLS BY MERCURY TUBE RELAYS

two arcs are moved by the operation of one or other of the two electromagnets (*LM* and *HM*). One contact brush is connected to the main discharge lead direct, whilst the second brush is connected to the discharge lead via the metal rectifier *MR*. The connexions are so arranged that, whilst brush No. 1 is moving from one segment to the next to switch counter e.m.f. cells into or out of circuit, the main discharge circuit is maintained via brush No. 2 and the metal rectifier. The direction of the rectifier is such that it offers a low impedance to the main discharge current but presents a high impedance to any circulatory currents from the counter e.m.f. cells. This rectifier must, of course, be capable of carrying the exchange load during the short time it is in circuit, but the rectifier unit need have only a small

number of elements since the back e.m.f. across it is limited to that of a single counter e.m.f. cell. The switch and the rectifier are comparatively cheap, whilst the scheme provides facilities for switching the counter e.m.f. cells into circuit singly, thereby providing a much closer control of the voltage on the exchange busbars.

Control of Charge. In a fully automatic float scheme it is necessary to provide some means whereby the operating current is switched off when the battery becomes fully charged and to reconnect the charging circuit at some predetermined value of discharge. The usual method of providing this control is to insert an ampere-hour meter in the battery circuit. This ampere-hour meter is provided with contacts which operate at various points in the charge-discharge cycle. There are usually three sets of such contacts:

(1) The first set of contacts operates when the battery is fully charged and switches off the main charging circuit.

(2) The second set of contacts operates when the battery has discharged to approximately 3 or 4 per cent of its nominal capacity. These contacts re-establish the charging circuit.

(3) A third set of contacts is provided to give an alarm condition if, for any reason, the battery becomes discharged to the extent of 30 per cent of its nominal capacity.

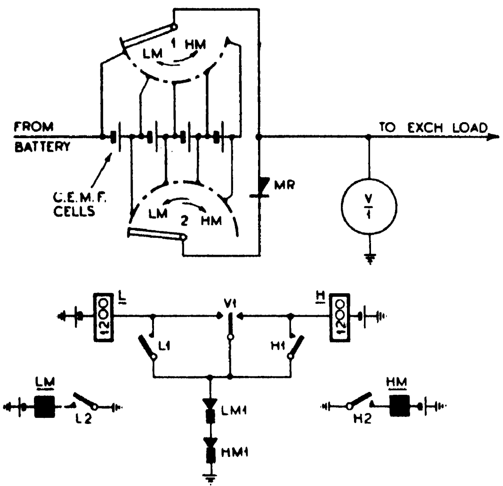


FIG. 788. METHOD OF SWITCHING LEAD-ACID C.E.M.F. CELLS UTILIZING A SIMPLE ROTARY SWITCH AND A METAL RECTIFIER

Provision must also be made to allow for the inevitable energy losses resulting from the electro-chemical conversions which occur during a cycle of charge and discharge. The ampere-hour efficiency of an average battery under normal working conditions is of the order of 90 per cent, i.e. it is necessary to put into the battery 100 Ah for every 90 Ah taken from the battery. Correction for these losses can be provided by arranging suitable gearing in the ampere-hour meter, so that rotation of one division in the charge direction requires approximately 20 per cent more energy than a rotation of one division in the discharge direction.

It is also necessary to make some provision for the losses due to local action within the cells of the battery. The amount of energy lost due to this cause is a function of time and is not determined by the movements of the ampere-hour meter. Such losses can be made up by providing a trickle charge circuit to the battery when the main charging circuit is disconnected. The value of this current is, of course, determined by the ampere-hour capacity of the batteries installed. (It should provide a charge at the 2500-hour rate.)

There is also a practical problem in automatic float schemes where the discharge current may be very small. At such exchanges an appreciable proportion of the total energy consumption may be absorbed by very small discharge currents which are insufficient to operate the ampere-hour meter. If these conditions apply it is necessary to provide an artificial load to ensure correct operation of the ampere-hour meter when the normal discharge current is small.

Fig. 789 shows a typical charge control circuit element. The main charge is switched by the mercury contact relay *B*, which in turn is controlled indirectly by the contacts on the ampere-hour meter. Let it be assumed that the charging circuit is connected, i.e. that relay *B* is operated. If the exchange load is light, most of the output from the rectifier passes through the ampere-hour meter to charge the battery. The meter is set so that when the pointer reaches O the battery will be in a fully-charged condition. At this point, contact ***AH*1** operates to complete a circuit for relay *AHA* to the battery at ***B*2**. ***AHA*1** provides a local holding circuit, whilst ***AHA*2** operates the "restore" coil of mercury switch *B*. Contacts *B*1 (mercury tube) now disconnect the main charging circuit. The exchange load is now met entirely by the battery, and in due course the ampere-hour meter reaches a point when the battery is 3 per cent discharged. Contacts ***AH*2** now operate to complete a circuit for relay *AHB*. ***AHB*1** holds this relay, whilst ***AHB*2** completes a circuit for the operating solenoid of mercury switch *B*. ***B*1** now reconnects the charging rectifier.

If, for any abnormal reason, the total discharge

over a period is in excess of the output of the rectifier, the ampere-hour meter may show a progressively increasing degree of discharge. If this condition allows the battery to discharge to 30 per cent of its capacity, contacts ***AH*3** operate to complete a circuit for relay *E*. *E* locks via ***E*1*x***, whilst ***E*2** initiates alarm conditions. The alarm circuit remains operated in this way until it is re-set by the operation of the "restore" key.

The trickle charge necessary to make up the losses due to local action is obtained by shunting contact *B*1 by a resistor of suitable value.

Circuit Noise. In any power supply scheme where motor generator sets or rectifiers are floated across the exchange busbars, there is always a danger that the charging equipment may produce noise on the speech circuits of the exchange. The output of all static rectifiers and generators contains an alternating component which is superimposed on the direct current output. This alternating ripple is usually very complex and may contain frequencies extending over a very wide range.

Similar alternating voltages are impressed on the d.c. output from static rectifier equipment. With a single-phase full-wave rectifier, the most important component is a frequency of twice that of the supply mains (i.e. usually 100 c/s). If three-phase rectifier equipment is in use, the most important ripple frequency is six times the mains frequency (i.e. 300 c/s). In addition to these, however, any rectifier produces a whole range of harmonics (theoretically to infinity) but, fortunately, these higher-frequency components are usually of lower amplitude.

The degree of disturbance to telephone speech depends not so much on the amplitude of the ripple voltage as upon the *frequency* of the disturbance. A comparatively small ripple voltage at, say, 800 c/s can cause very much more interference on a telephone circuit than a ripple voltage which is many times larger but has a frequency of, say, 100 or 300 c/s. This is, of course, due to the higher sensitivity of telephone apparatus and the low attenuation of telephone circuits at frequencies near the mean of the normal commercial speech range.

It is of material advantage to have some means whereby the disturbing effect of a number of different sources can be measured and compared. A circuit noise meter (or psophometer) has been developed for the measurement of the disturbance on telephone circuits. The instrument is essentially a valve voltmeter with suitable networks to provide weighting factors for the various frequencies. The calibration of this instrument has been decided by international agreement so that psophometer readings obtained by different telephone administrations all have the same significance.

It is interesting to examine the characteristics of the weighting curve of a noise meter to the C.C.I.F. Specification. Fig. 790 shows the mean response characteristic of the noise meter circuit at various frequencies. A note of 800 c/s is considered as unity and on this basis a note of 1050 c/s has a weighting factor of approximately 1·9. On the other hand, a note of 100 c/s is given a weighting

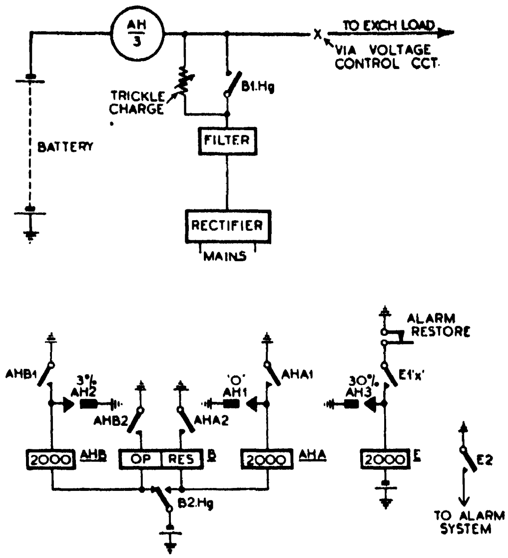


Fig. 789. Ampere-hour Meter Control of Charge

factor of 0·1. Thus the same reading is obtained on the meter when 10 V a.c. at 100 c/s is applied as when 1 V at 800 c/s is connected. The reading obtained on the meter when a ripple consisting of a complex range of frequencies is applied is the same as would be obtained from a pure 800 c/s note of such a magnitude that the same disturbing effect is produced in the telephone system.

It has been found by experience that it is possible to tolerate up to a maximum of 2 mV (weighted voltage) on the busbars of a telephone exchange before the disturbance becomes excessive. If the exchange is supplied by two or more generators (or rectifiers) the ripple output from each machine must be such that the combined voltage is within the 2 mV limit. As a rough approximation it can be assumed that the contribution from each machine would not exceed 2 mV divided by the square root of the number of machines.

Sources of Noise. The noise on the transmission circuits of an exchange depends upon:

(*a*) The amplitude and frequency of the alternating e.m.f. which is generated in the charging plant.

(*b*) The internal impedance of this source.

(*c*) The impedance of the battery circuit.

(*d*) The impedance of the exchange load.

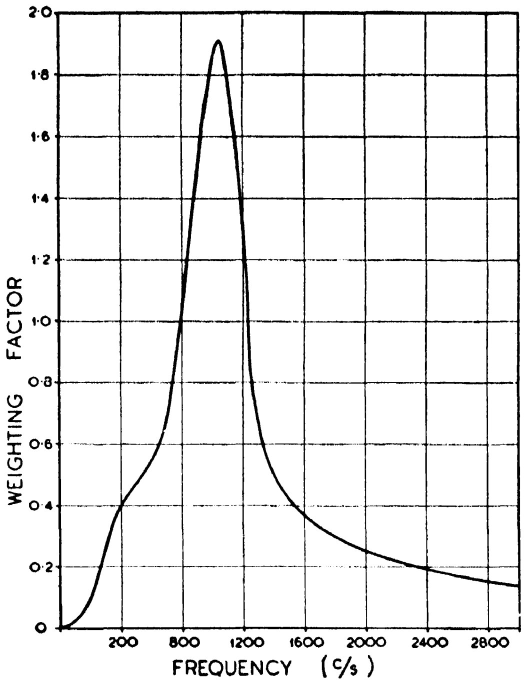


FIG. 790. AVERAGE WEIGHTING CURVE OF CIRCUIT NOISE METER (PSOPHOMETER) (C.C.I.F. Specification)

(*e*) The electrical characteristics of any smoothing circuit connected between the generating plant and the battery.

In most cases the load impedance can be ignored since it is usually much greater in magnitude than the parallel impedance of the battery circuit.

The ripple voltage from a d.c. generator may contain the following frequencies:

(*a*) The fundamental frequency generated in the armature and the harmonics of this frequency.

(*b*) The slot ripple frequency and its harmonics.

(*c*) The commutator ripple frequency and the harmonics of this frequency.

Tests have shown that the ripple voltage increases with the value of the current supplied by the generator, the main component being at slot ripple frequency due to the current in the armature windings. (The slot ripple frequency is given by $N.S/60$ c/s where N is the armature speed (r.p.m.) and S is the number of armature slots.) Calculations and a number of practical tests have indicated that the amplitude of the noise e.m.f. (at full load) is approximately 1 per cent of the d.c. voltage of the machine.

The value of the slot ripple can be minimized by designing a generator with a high reluctance between the slots and the pole-pieces, and by proportioning the slots and pole-shoes so that the rate of change of reluctance is small. In some of the earlier d.c. generators supplied for telephone purposes the slots were completely enclosed. Sometimes skewed slots were also used, and the pole-shoes themselves were chamfered to minimize the rate of change of magnetic reluctance. These special features, however, produced a very expensive machine and the d.c. efficiency was lower than on normal machines with small air gaps. Moreover, the high inductance of the armature windings produced certain commutation difficulties which involved the provision of special brushes and a large number of commutator segments in order to reduce sparking. It is now the standard practice to use ordinary commercial machines and to rely upon some form of filter to attentuate the slot ripple.

The noise ripple from static rectifiers consists mainly of the fundamental ripple frequency. On single-phase full-wave rectifiers connected to 50 c/s mains, this fundamental frequency is 100 c/s. For three-phase full-wave rectifiers (at the same mains frequency) the main ripple frequency occurs at 300 c/s. In addition to the main ripple frequency, other components at the higher harmonic frequencies are also present but, if a low-pass filter is designed to cater for the main frequency, such a filter offers a very high attenuation to the higher frequency harmonics, i.e. they need not be considered in the design of the filter. It has been found from experience that the noise e.m.f. at the main ripple frequency can, for design purposes, be assumed to be

(*a*) 1·2 per cent of the d.c. output voltage for a single-phase full-wave rectifier, and

(*b*) 1·5 per cent of the d.c. output voltage for a three-phase full-wave rectifier.

For a given value of noise e.m.f. at the source, the extent of disturbance on telephone circuits is largely determined by the electrical characteristics of the machines and the battery circuit. The a.c. resistance of a generator armature is usually very small compared with the reactance and can be neglected. The inductance of a d.c.

generator can be calculated from the empirical formula:

$$L = KV/IN \text{ henries}$$

where K = a constant (usually about 1·4),
V = the rated output voltage of the generator,
I = maximum output current of generator (amperes),
N = speed of machine (r.p.m.).

The internal impedance of a static rectifier is determined partly by the resistance of the rectifier itself, and partly by the leakage impedance of the transformer, etc. The values vary considerably for rectifiers of different rating and voltage.

The impedance of the battery circuit must include the characteristics of the cable system between the batteries and the power switchboard. Very approximately the resistance of a battery can be assumed to be:

$$R = KN/Q \text{ ohms}$$

where K = a constant (usually about 0·25),
N = number of cells,
Q = capacity of battery (ampere-hours).

The inductance of the battery itself varies considerably with the lay-out of cells, but the following approximate formula may be used for calculation purposes:

$$L = \frac{4}{10^9}\left[(a+b)\log_\varepsilon\frac{2ab}{r} - a\log_\varepsilon(a+d) - b\log_\varepsilon(b+d)\right] \text{ henries}$$

where a and b = the lengths of the sides of the rectangle formed by the cells (cm),
d = length of the diagonal (i.e. $\sqrt{a^2+b^2}$),
r = $0{\cdot}02Q^{0\cdot 7}$ (where Q is the ampere-hour capacity of the battery).

The capacitance of the battery can usually be neglected in the case of large batteries. The capacitance of batteries of small capacity can be calculated from:

$$C = 20\,000 \times Q/N \text{ (microfarads)}$$

where Q = ampere-hour capacity,
N = No. of cells.

The electrical characteristics of the leads connecting the battery to the power board are primarily determined by:

(*a*) the a.c. resistance of the conductors, and
(*b*) the inductance of the loop.

An approximate value for the latter can be obtained by the approximate formula:

$$L = \frac{4}{10^9} \times l \times \log_\varepsilon \frac{d}{r}$$

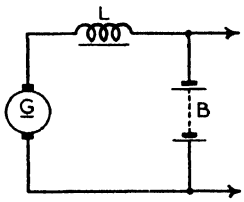
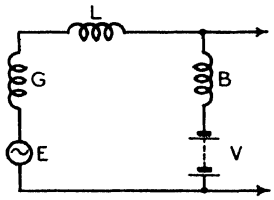
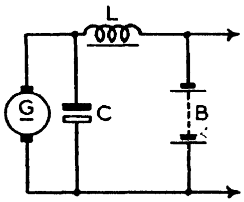
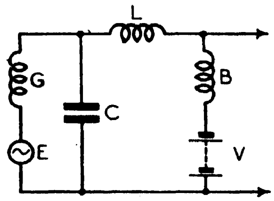
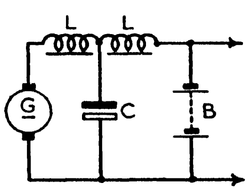
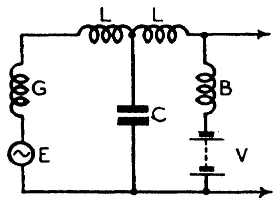
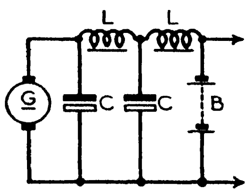
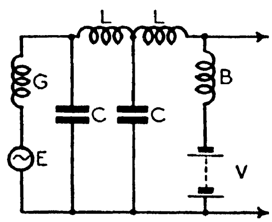
where l = length of the leads (cm),
d = separation (cm),
r = radius of each conductor (cm).

With the normal lay-out of batteries, it is usually sufficient, for filter design purposes, to assume an overall inductance of about 20 mH and to ignore the resistive and capacitative factors.

Filter Circuits. Fig. 791 shows the more common types of filter used in the smoothing equipment of an exchange power plant. The most convenient method of approach to filter design is to regard the arrangement as an a.c. network and to calculate the current in the various branches by the application of Kirchhoff's Laws, assuming that the generator or rectifier is the source of a.c. It is difficult to apply wave filter theory to such filters since they are never closed by their characteristic impedance but always by a very low impedance battery. The second column of Fig. 791 shows the approximate equivalent a.c. circuit for each type of filter, whilst the third column gives an approximate expression for the attentuation with each arrangement. The design of a filter for a d.c. generator is based on the slot ripple frequency but, to ensure that the filter will have a reasonable attenuation to any lower frequency components, it is usual to design the filter so that the main resonant frequency does not exceed 200 c/s. Filters designed for rectifiers are based on the main ripple frequency (i.e. 100 c/s for single-phase full-wave rectifiers, and 300 c/s for three-phase full-wave rectifiers).

It is customary to allow a factor of safety of up to 4 in the design of filters to cater for inaccuracies in the assumed electrical constants of the circuit. A filter for a small motor generator or rectifier is designed to give four times the required attenuation, whilst for larger outputs (say, over 300 A), a factor of safety of 2 is employed in order to avoid excessive costs.

The single-choke type of filter is usually the most satisfactory arrangement for very small generators or rectifiers, but with this arrangement the cost of the choke becomes excessive for larger outputs. Capacitors are not normally connected across the battery side of the filter, for in this position they do not contribute to the smoothing (i.e. the voltage developed across the capacitor is also applied directly to the exchange battery). Filters for static rectifiers should not employ capacitors

TYPE	CIRCUIT	APPROX. EQUIVALENT A.C. CIRCUIT	APPROX. ATTENUATION
SINGLE CHOKE			$\frac{E}{V} = 1 + \frac{L+G}{B}$
ONE SECTION			$\frac{E}{V} = 1 + \frac{L+G}{B} - \frac{\omega^2 CG}{B}(L+B)$
T SECTION			$\frac{E}{V} = 1 + \frac{2L+G}{B} - \frac{\omega^2 C}{B}(L+G)(L+B)$
TWO SECTIONS			$\frac{E}{V} = 1 + \frac{2L+G}{B} - \frac{\omega^2 C}{B}\{L(L+3G)+B(L+2G)\} + \frac{\omega^4 C^2 LG}{B}$

G = INDUCTANCE OF GENERATOR (H)

B = INDUCTANCE OF BATTERY (H)

L = INDUCTANCE OF EACH SERIES CHOKE (H)

C = CAPACITY OF EACH SHUNT CAPACITOR (F)

E = ALTERNATING E.M.F. OF GENERATOR (V)

V = ALTERNATING P.D. ACROSS BATTERY (V)

$\omega = 2\pi f$, WHERE f = FREQUENCY OF E.M.F. (C/s)

FIG. 791. TYPICAL SMOOTHING FILTER NETWORKS

directly connected across the rectifier element, since, due to the low impedance of the latter, the effect is virtually to short-circuit the rectifier so far as ripple currents are concerned. This results in overloading the capacitor, and does not confer any real advantage as regards smoothing, since the voltage across the capacitor is merely applied to the next stage of the filter.

The capacitors used in power filters are normally of the electrolytic type to obtain a large capacity with reasonable cost and small mounting space. The life of these electrolytic capacitors varies considerably, and under unfavourable conditions may be comparatively short. It is the normal practice to guard against breakdown due to the failure of an electrolytic capacitor by limiting the capacity of each capacitor unit to 1000 μF, a number of such units being connected in parallel in order to give the required overall capacitance. Each rectifier unit is separately fused. A typical smoothing circuit for a 300 A generator would consist of a T-section filter with two inductors each of 500 mH with a bank of electrolytic capacitors totalling 5000 μF connected at the centre point. Such a unit can be accommodated in a steel case some 3 ft long, 3 ft high, and approximately 18 in. wide.

The lay-out of the components in the filter unit is of some importance in order to obtain the maximum smoothing effect. Leads which carry ripple current in opposite directions should be run as close together as possible. The capacitor leads should also be run close together to reduce their inductive impedance, and the length of the leads should be as short as possible.

Divided Battery Float Scheme. This is the standard design of power plant for all new exchanges where the consumption at the ultimate date exceeds 2000 Ah per day. The divided battery float scheme employs two batteries each of 25 cells, the total capacity of both batteries being roughly equal to the daily ampere-hour consumption of the exchange. One small and one or more large motor generators are installed, and the generators are floated across one of the batteries and the exchange load. Automatic voltage regulators (associated with the generator field circuits) maintain the p.d. on the exchange busbars between 50·5 and 51·75 V. The second battery is held in reserve, and the losses due to local action which occur during the waiting period are made up by means of a trickle charge. The two batteries are changed over at weekly intervals, so that any losses which occur in the working battery (due to its low floating voltage) are made up during the following week when this battery is on trickle charge. (The divided battery float scheme is based on the principles already considered in Fig. 769.)

The plant is provided in six standard sizes to cater for exchanges with daily loads ranging from 2000 Ah to 10 000 Ah. Generators are provided on the following basis:

Ultimate Daily Load (ampere-hours)	Ultimate No. of Generators	Current Output of Generators (amperes)
2000/3000	1 2	100 200
3000/4000	1 2	100 300
4000/5000	1 2	100 400
5000/6000	1 2	200 400
6000/8000	1 2	200 500
8000/10 000	1 3	200 500

The number of machines provided during the early life of the exchange is determined by the load at that time. In all cases, however, it is usual to provide one small and one large machine at the outset and to add more of the larger type machines as the exchange grows.

The motor generator sets may be used either singly or in various combinations to provide the most economical running conditions at all times of the day and night. (The highest efficiency occurs when the machines in use are run as near as possible at full load.) In Fig. 792, for example, the exchange is assumed to be equipped with one 100 A generator and two 400 A generators. The exchange load during the night period is small, and the small (100 A) generator will suffice to meet the current demands. At 7 a.m. the load commences to rise, and the small generator is replaced by a single 400 A generator. At 9 a.m. this single 400 A generator is augmented by the second 400 A generator to meet the peak load between 9 a.m. and noon. The traffic on the exchange decreases during the luncheon interval so that it is possible to take off one of the 400 A generators between noon and 2 p.m. At this time the afternoon traffic is commencing to rise and, since this traffic is slightly higher than the capacity of a single 400 A generator, the 100 A generator

is added between 2 p.m. and 4 p.m. As the traffic decreases at the end of the business day, the load on the 400 A generator rapidly decreases until, at 8 p.m., it is possible to replace this generator by the smaller 100 A machine. If one of the batteries becomes discharged after a prolonged mains failure, it can be recharged by one of the 400 A generators at any time outside the peak period of the day when this generator is in use to supply the exchange load.

Only two automatic voltage regulators are required even although there may be three or more motor generator sets. When two or more machines are paralleled, the machines which are not fitted with regulators are adjusted (by hand) to take a considerable proportion of the load, and the automatically controlled machines will deal with the varying load in excess of the output of the hand-regulated machines.

Fig. 793 shows the circuit arrangements of the divided battery float scheme. By means of knife switches it is possible:

(*a*) To connect the trickle charge unit to either of the two batteries as desired.

(*b*) To connect any of the generators to either of the two batteries.

(*c*) To connect the discharge lead to either battery.

(*d*) To couple both batteries to the main discharge lead.

The automatic voltage regulators are controlled directly by the p.d. on the exchange busbars, whilst each machine circuit contains a suitable filter network to minimize ripple voltage applied to the exchange discharge circuit. The circuit breakers are of the usual type, an alarm system being provided (relay *CB*) to draw attention to the opening of any breaker. The contact voltmeter provides visible and audible alarms if the p.d. on the exchange is less than or greater than the prescribed limits.

Fig. 794 shows a typical divided battery float installation. A large machine is shown in the foreground, whilst the smaller (night load) machine is nearer the power board. The left-hand panel on the latter accommodates the ringer changeover equipment and the miscellaneous apparatus associated with the ringing and tone supplies. The next panel accommodates the various meters, the "coupling" switch, and the "discharge" switch. The next three bays are each associated with one of the generators and contain the circuit breaker, the knife-edge switch for association of the generator with either of the two batteries, and the automatic voltage regulator. In this particular case the regulators are of the dynamometer type described in Fig. 771. The motor control gear is fitted on special frameworks as near as possible to the motors themselves. The covered cable trench between the machine piers and the power board will be noted.

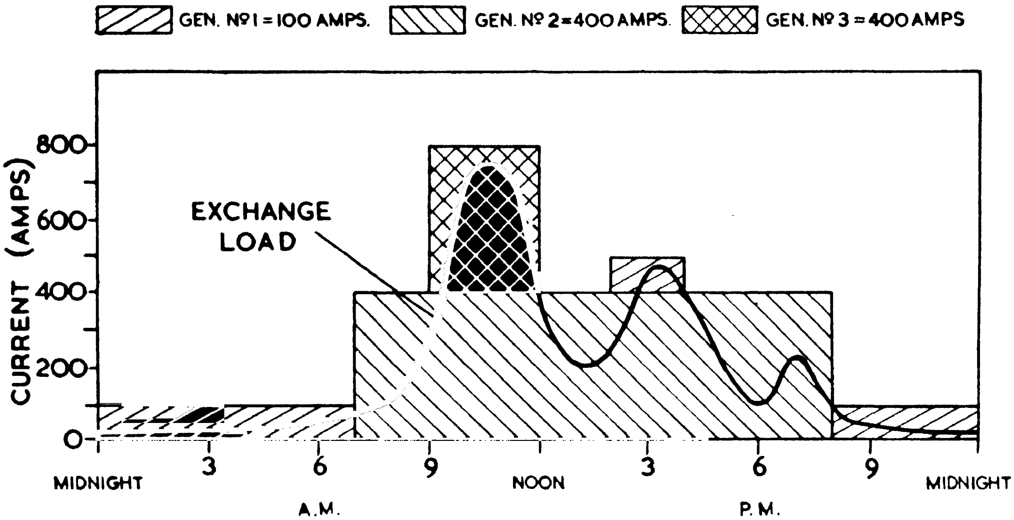


Fig. 792. Showing Typical Use of Generators in a Divided Battery Float Scheme

Parallel Battery Float Scheme. The parallel battery power scheme is the standard arrangement for exchanges of medium size where the ultimate load is from 100 to 2000 Ah per day. The scheme is fully automatic and follows the principle already

considered in Fig. 770. There are two batteries each of 25 cells, and the batteries are normally connected in parallel to the exchange load. If a.c. public supply mains are available, static rectifier equipment is used for charging purposes. In the smaller exchanges rectifiers of the selenium or copper oxide type are usually more economical, but in larger installations the rectifiers are of the mercury arc type (see Volume I).

No attempt is made to control the voltage at the battery terminals, and this voltage may vary over a wide range depending upon the state of the battery and whether or not it is charging or discharging. The voltage on the exchange busbars is maintained constant throughout the cycles of charge and discharge by the provision of 8 counter e.m.f. cells of the nickel-alkaline type (q.v.) which are switched into circuit by means of latching type contactors indirectly controlled from a contact voltmeter. The charge is regulated by means of an ampere-hour meter in series with the battery. This ampere-hour meter is arranged to cut off the rectifiers when the battery is fully charged, and to restart the circuit when the battery discharges to approximately 4 per cent of its capacity. Further contacts on the ampere-hour meter are arranged to give an alarm if the battery should become more than about 30 per cent discharged.

The total battery capacity (i.e. the capacity of both batteries together) is approximately equal to the 24-hour load of the exchange. It is normal practice to provide two rectifiers initially, and to add a third rectifier as the exchange grows. A small exchange where the anticipated ultimate load is, say, 200 Ah per day would have two 5 A dry plate rectifiers installed at the outset. A third rectifier of similar capacity would be added as required to meet the increasing load during the life of the exchange. Similarly, a fairly large exchange where the ultimate daily load is expected to be of the order of 2000 Ah would require two 50 A mercury arc rectifiers at the outset, and provision is made for the installation of a third such rectifier at a later date.

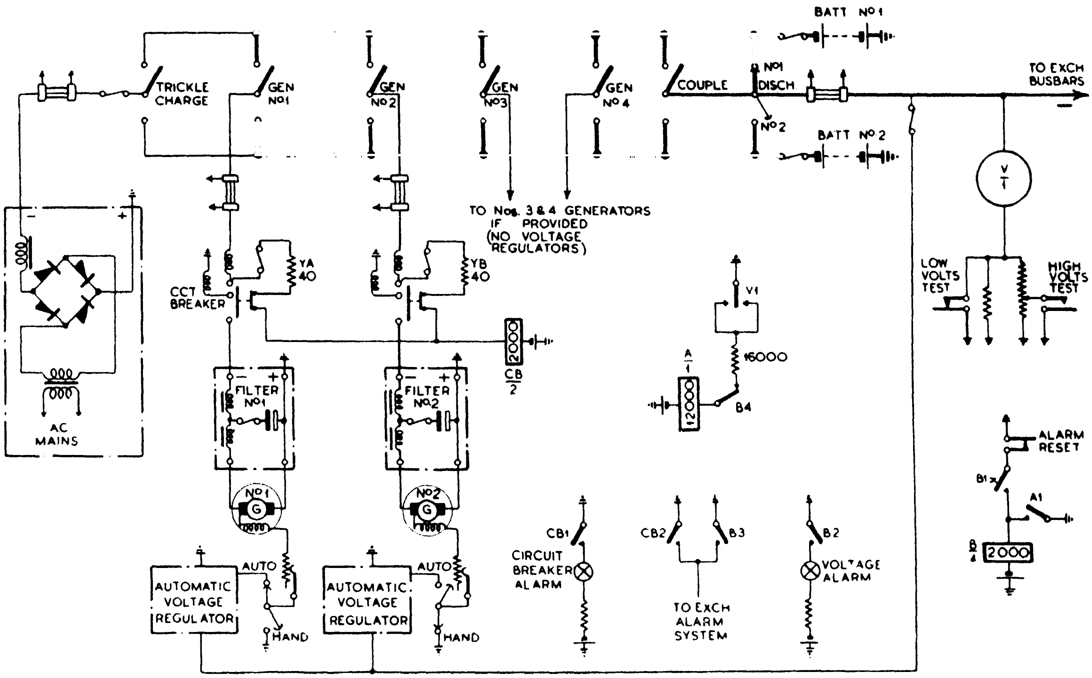


FIG. 793. CIRCUIT ARRANGEMENTS OF DIVIDED BATTERY FLOAT SCHEME

Where the public supply mains are direct current, it is necessary to provide motor generator sets which are automatically started when the battery discharges by the prescribed amount. In such installations it is necessary to provide an artificial load so that the ampere-hour meter operates satisfactorily at low loads when the charging plant is not in operation. This facility is not required in a.c. cases, since small discharges of this type are compensated for by the trickle charge circuit.

Fig. 795 shows the main circuit arrangements of

a parallel battery float plant. The elements concerned with voltage and charge control have already been examined in detail earlier in this chapter. Relay *BA* or *BB* operates in parallel with the mercury switch (*ML* or *MH*) under low-volt or high-volt conditions. ***BA*2** or ***BB*2** connects relay *P* to the 30 sec earth pulse. *P* operates to the short circuit from across relay *AD*. The latter now operates in series with *AC*. ***AD*3** places the holding circuit of *AC* and *AD* under the control of contact *D*4, whilst ***AD*1** prepares the circuit for relay *AE*. Contacts ***AC*2** and ***AD*2** re-operate relay *P*, and the latter energizes relay *PS* as before. After a 30-sec delay period, relay *D* operates and

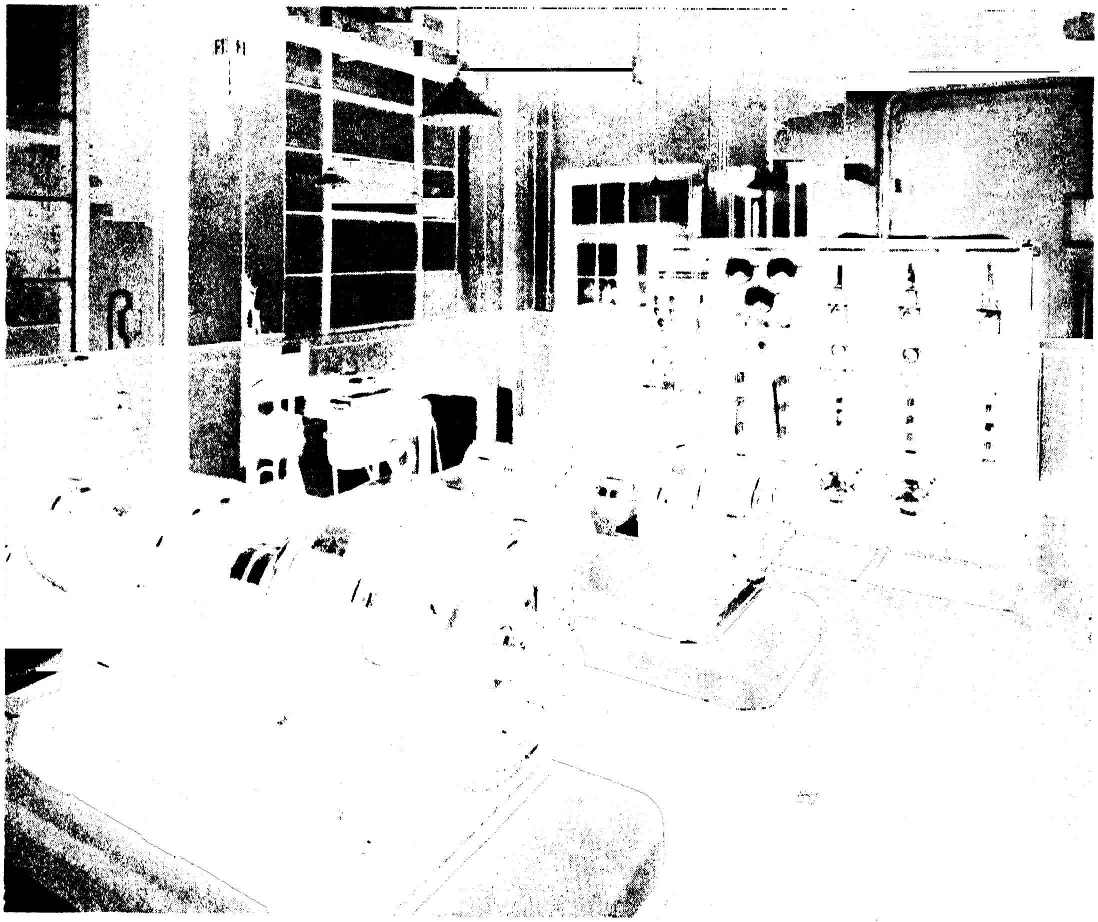


FIG. 794. GENERAL VIEW OF POWER ROOM—DIVIDED BATTERY FLOAT TYPE PLANT

the first pulse and at ***P*1** prepares the circuit for the operation of *PS* at the end of the pulse. ***PS*1** now connects relay *D* to the pulse supply and, at the next pulse, *D* operates and locks via ***D*4**. ***D*2** or ***D*3** connects relay *AC* to test for persistence of the low- or high-volt condition. ***D*1** releases *BA* or *BB* and *BA*2 or *BB*2 releases relays *P* and *PS*. The latter releases *D*.

If, due to a fault, a high- or low-volt condition persists, relay *AC* operates to the earth at *MH*2, and, when *D* releases, contact *D*2 (or *D*3) removes in turn releases *AC* and *AD*. (*AD* is slugged.) *AC*2 releases *P*, and after a delay period relay *PS* restores. *PS*2 in turn disconnects the holding circuit of relay *D*, and the latter releases. During the time that *D* is operated and during the slow release period of *AD*, relay *AE* tests for an earth via ***AD*1**, ***D*3**, and ***H*2** (or ***D*2** and ***L*2**). If the high- or low-volt condition still persists, *AE* operates and holds via contact ***AE*1** to the earth at the "receiving attention" key. ***AE*3** completes the alarm circuit, and ***AE*2** operates mercury

switch *S*. *S1* operates contactor No. 5, and the closure of this contactor short-circuits all the counter e.m.f. cells. The exchange is now connected direct to the battery but, since the latter is not on charge under these conditions, the voltage applied to the busbars is approximately 50 V.

The auxiliary contacts of contactor No. 5 hold relay *AE* via *N4*. The subsequent operation of the "receiving attention" key disconnects the alarms and the holding circuit of relay *AE*.

The battery supply (*V*) to contacts *MH*1, *ML*1, and various relays is fed via auxiliary contacts on contactor No. 5. These auxiliary contacts can be re-set ("re-set control circuits") in advance of the main contacts so that tests can be made on the sequence of operations without disturbing the voltage across the exchange supply. After the circuit has been proved satisfactory, the main contacts of contactor No. 5 may be re-set, thereby disconnecting the holding circuit of relay *AE*.

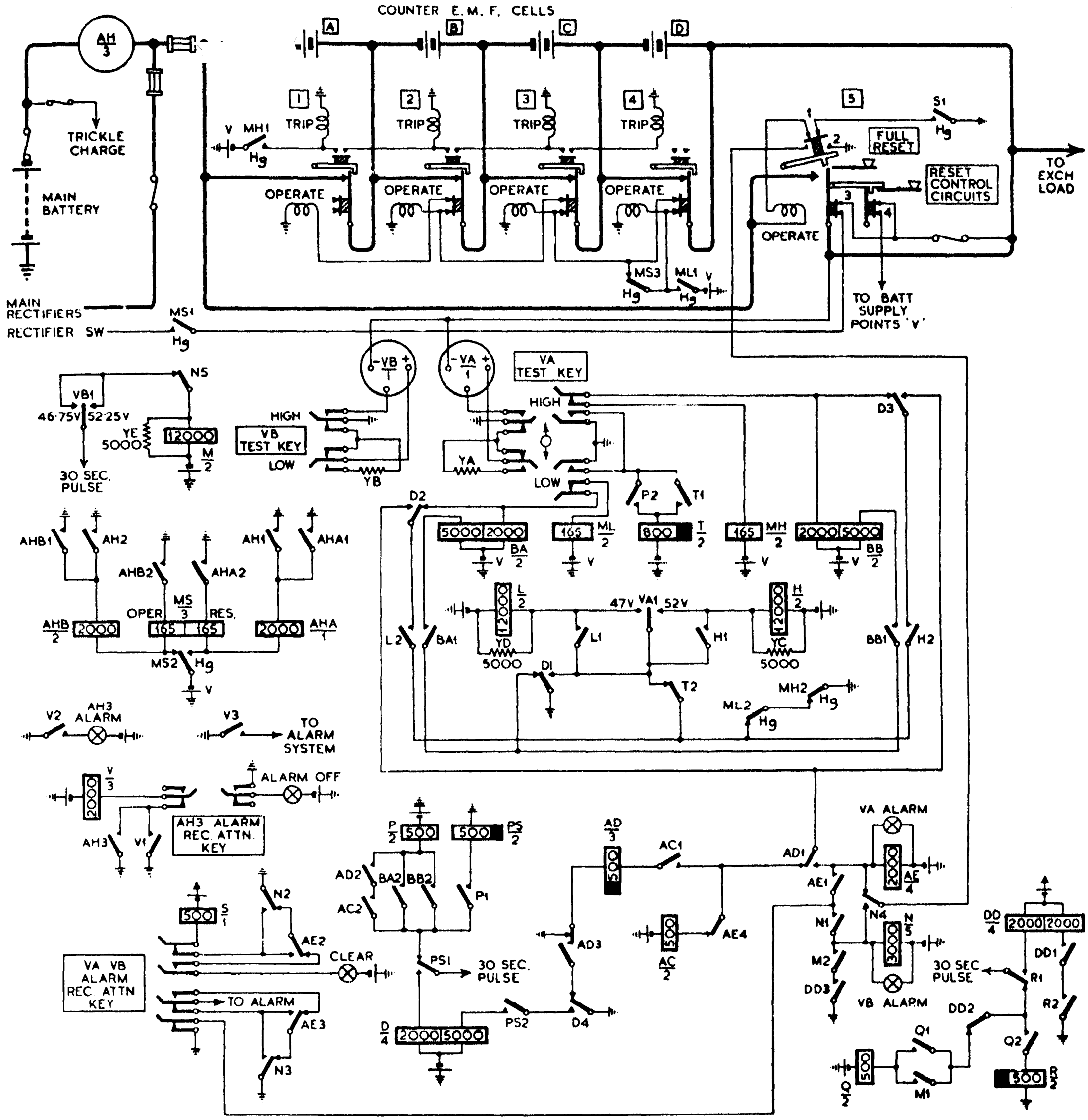


FIG. 795. PARALLEL BATTERY FLOAT CIRCUIT

It, for any reason, a high- or a low-volt condition fails to complete the alarm circuit controlled by voltmeter *VA*, the contacts of volt- and holds via ***DD*1** and ***R*2**. ***DD*2** disconnects the circuit of relay *Q*, and the latter in turn disconnects *R*. *R*2 now releases *DD*. During the

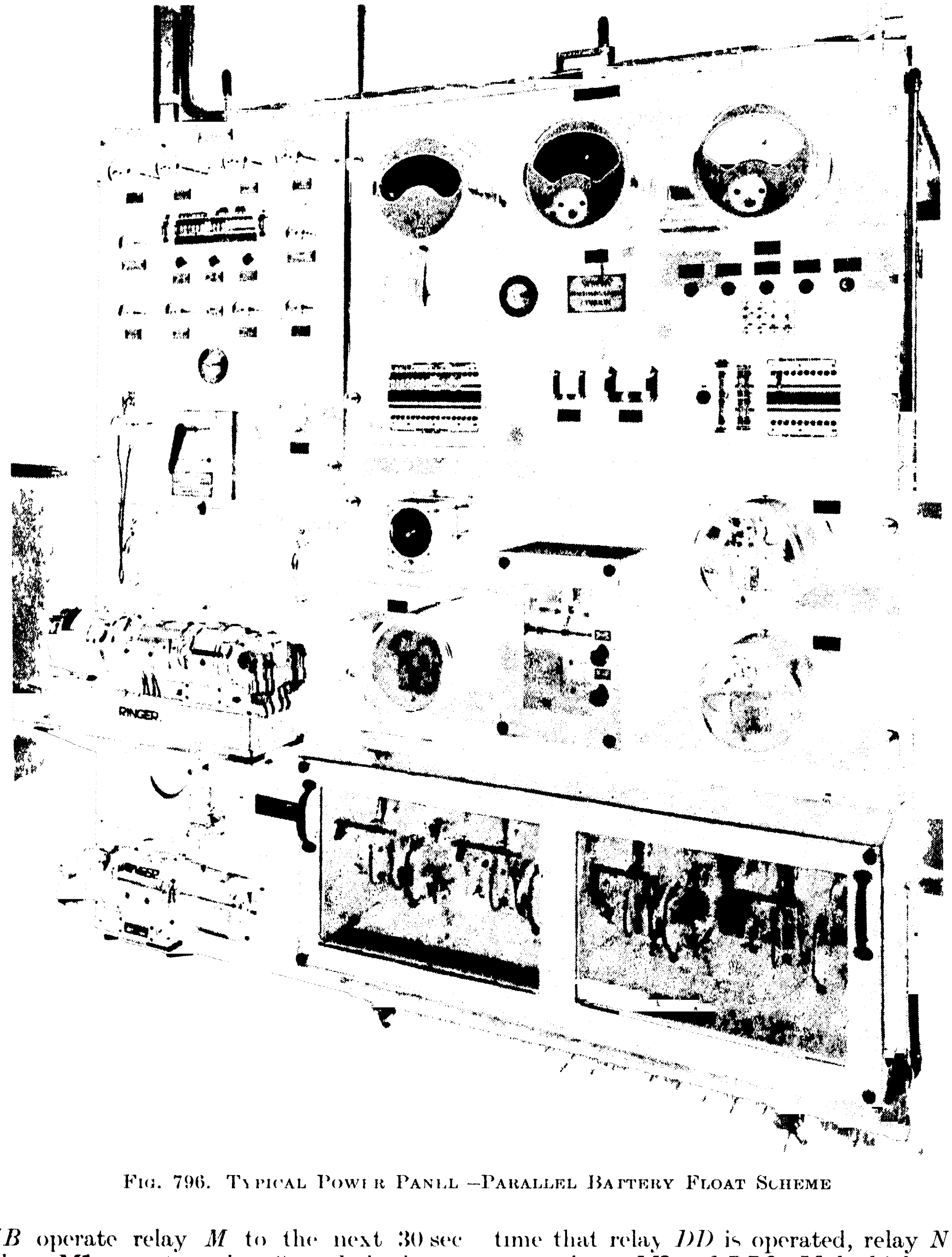


FIG. 796. TYPICAL POWER PANEL—PARALLEL BATTERY FLOAT SCHEME

meter *VB* operate relay *M* to the next 30 sec earth pulse. ***M*1** operates relay *Q*, and the latter holds via ***Q*1**. When the earth pulse is disconnected, relay *R* operates in series with *Q* and, at the next pulse (30 sec later), relay *DD* operates via ***R*1** time that relay *DD* is operated, relay *N* tests for an earth via ***M*2** and ***DD*3**. If the high- or low-volt condition persists, *N* operates and locks. ***N*3** completes the alarm circuit, whilst ***N*2** operates mercury switch *S*, and the latter operates

contactor No. 5 as already described. Relay N is now held via the auxiliary contacts of contactor No. 5, and **$N5$** disconnects relay M to prevent its re-operation.

Under normal working conditions, the disconnexion of the charge circuit when the battery is fully charged causes an abnormally large fall in the p.d. at the battery terminals. Under these conditions it may be necessary to cut out two groups of counter e.m.f. cells at one operation. If the fourth group of cells is in circuit, **$MS3$** enables contactors Nos. 3 and 4 to operate together and short-circuit counter e.m.f. cell groups 3 and 4 at the same time.

If, for any reason, the battery discharges to more than 30 per cent, contact **$AH3$** operates relay V and contacts **$V2$** and **$V3$** set up alarm conditions. Test keys are provided to simulate high- and low-volt conditions in order to test the various alarm circuits.

Fig. 796 shows a typical power panel arranged for parallel battery float working. The ringer panel with its automatic changeover circuits, etc., is on the extreme left. The counter e.m.f. cell switching contactors are enclosed in the glass-fronted cover at the bottom of the right-hand portion of the panel. The emergency contactor (No. 5), the mercury tube relays, and the ampere-hour meter are mounted immediately above, whilst the top of the panel contains the contact voltmeters and an ammeter. The ordinary telephone type controlling relays are mounted on suitable panels behind the power board.

Parallel Battery Float Scheme with Motor-switch. Fig. 797 shows an alternative parallel battery float scheme. The main feature of this scheme is the use of a motor-driven unit (see Fig. 785) in place of the contactors for the switching of the counter e.m.f. cells. The circuit was initially designed for the conversion of charge-discharge systems at existing exchanges. Apart from the simpler circuit arrangements, the equipment requires less floor space than the method described in previous paragraphs, is less costly and (with the exception of the motor-driven switch) all the apparatus is of the standard telephone type.

As before, the storage system employs two batteries joined permanently in parallel, and is connected to the exchange busbars via an ampere-hour meter. The ampere-hour meter is actuated by both charge and discharge currents, and is fitted with the three sets of contacts which close at various points of the charge-discharge cycle. Four groups, each of 2 counter e.m.f. cells, are provided and these cells are short-circuited as required by the motor-driven switch in order to keep the exchange busbar voltage within the prescribed limits. The switch motor is operated under the control of a contact voltmeter.

If the battery discharges to 4 per cent of the rated capacity, contact **$AH2$** operates to complete a circuit for relay CS. CS in operating locks via **$CS1$**, and at **$CS2$** completes the circuit for the operate coil of the mains switch SW. The charging circuit is now established and continues until the ampere-hour meter indicates zero. Contacts **$AH1$** now close and, by short-circuiting relay CS, disconnect the mains supply to the rectifier.

The voltage on the exchange busbar is controlled by contacts filled to the voltmeter VA. At a 50 V exchange the contacts are adjusted to operate at 47·5 V and 52 V. If the battery voltage rises to the maximum specified value, contact **$VA1$** operates and completes a circuit for relay H. H locks via **$H1$**, and at **$H2$** energizes the relief relay HR. Contact **$HR1$** completes a circuit for the motor-switch MS and at the same time energizes the braking magnet BM. The direction of rotation of the motor is such that the contact arm ($MS1$) moves to the left. Contact **$MS4$** is operated from a cam on the shaft of the motor-switch during the time when $MS1$ is moving between contact positions. The circuit is arranged so that **$MS4$** provides a locking circuit for HR independent of H during the transition period. By the time that $MS1$ has completed its step, the group of counter e.m.f. cells will have built up their voltage and reduced the p.d. at the exchange busbars, so that, when $MS4$ releases, $VA1$ should be normal. If the battery voltage continues to rise, **$VA1$** again re-operates H, and the process is continued until all the four groups of counter e.m.f. cells have been inserted in the discharge lead. Contacts **$MS3$** are arranged to open when the selector switch reaches position 4 to prevent any further operation of relay HR.

When the battery is on discharge, its voltage will fall until the p.d. at the power board reaches the specified minimum voltage. **$VA1$** now operates to the low-voltage condition and energizes relay L. **$L2$** completes a circuit for LR, and **$LR1$** energizes the motor of the switch unit via its second field coil $F2$. This causes the contact arm to move to the right, so that the counter e.m.f. cells are progressively short-circuited until such time as the busbar voltage is within the required limits. As before, contacts are provided (**$MS3$**) to prevent any further movement of the switch when it has reached position 0.

If, for any reason, (e.g. an excessive load or a mains failure) the battery becomes discharged by

more than 30 per cent of its capacity, contacts ***AH*3** are closed. The *V* relay is now energized and locks at ***V*1**, whilst contacts ***V*2** and ***V*3** set up alarm conditions. The alarm condition can only operating lag of some 20 sec. This delay period ensures that any momentary operation of *VB* does not give rise to the voltage alarm condition. If the condition persists for the operate time of

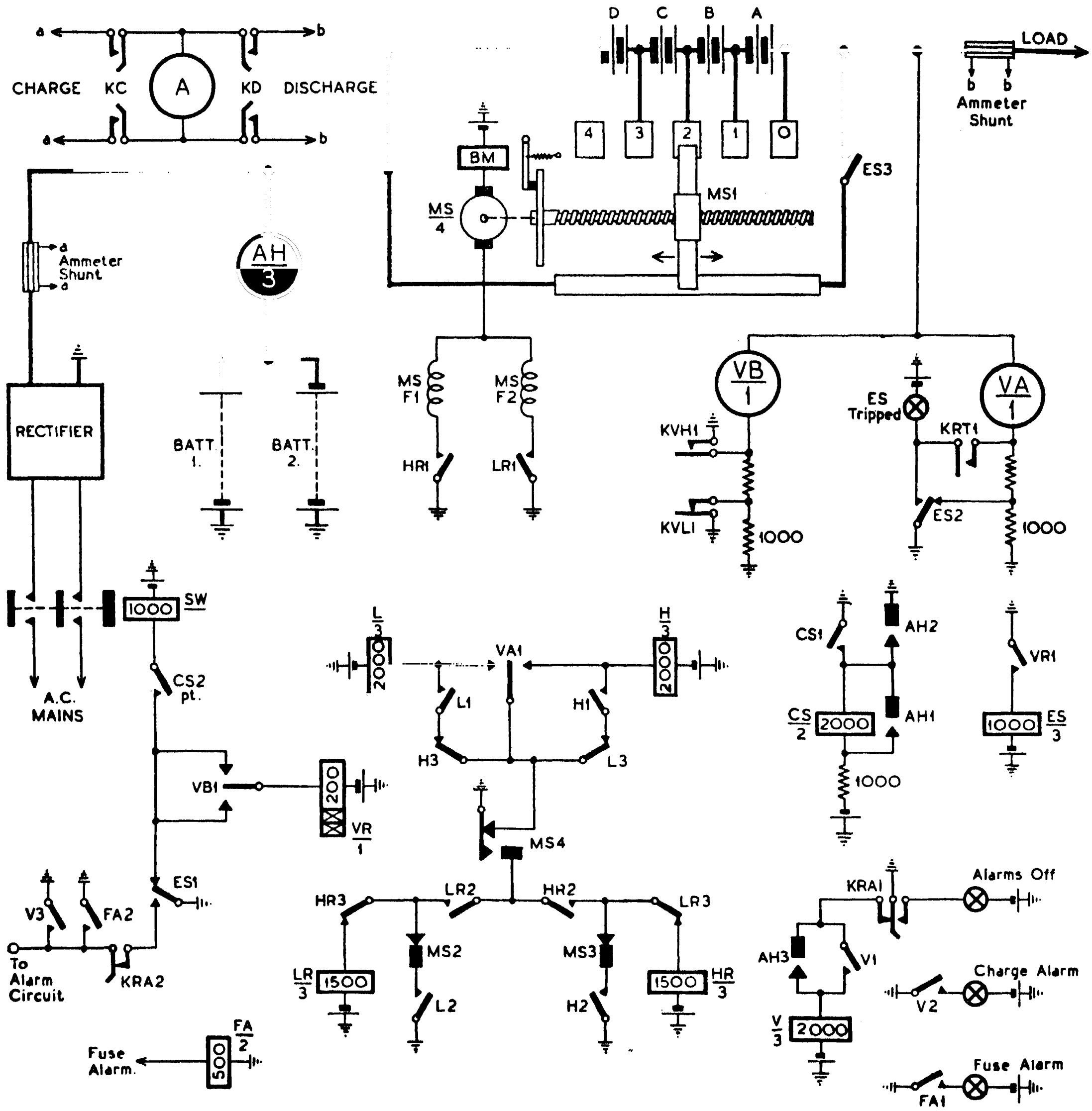


FIG. 797. PARALLEL BATTERY FLOAT CIRCUIT USING MOTOR-SWITCH

be restored by the operation of the *KRA* key when the plant has received attention.

The contacts of voltmeter *VB* are set at slightly wider limits than *VA* (in a 50 V case they are set at 47·25 V and 52·25 V) so that alarm conditions are set up if there is any failure of the voltage control circuit. Contact ***VB*1** energizes relay *VR*, which is of the thermal delay type and has an *VR*, ***VR*1** trips a contactor *ES* which, at ***ES*3**, short-circuits the voltage control switch and at ***ES*1** gives a prompt alarm. ***ES*2** lights the local alarm lamp. The *ES* relay is of special design and, when once operated, must be restored by hand. Routine test and voltage alarm test keys are provided so that functional tests of the power plant can be carried out.

Single Battery Automatic Power Plant. Fig. 798 shows the circuit arrangements of a somewhat simpler power circuit designed for use at small exchanges where the ultimate load does not exceed 100 Ah per day. The method of working is substantially similar to that used in the parallel e.m.f. cells of the lead-acid type. These cells are switched in and out of circuit as required by mercury tube relays under the control of a contact voltmeter. The circuit principles both for voltage control and for charge control have already been considered in conjunction with Figs. 787 and 789.

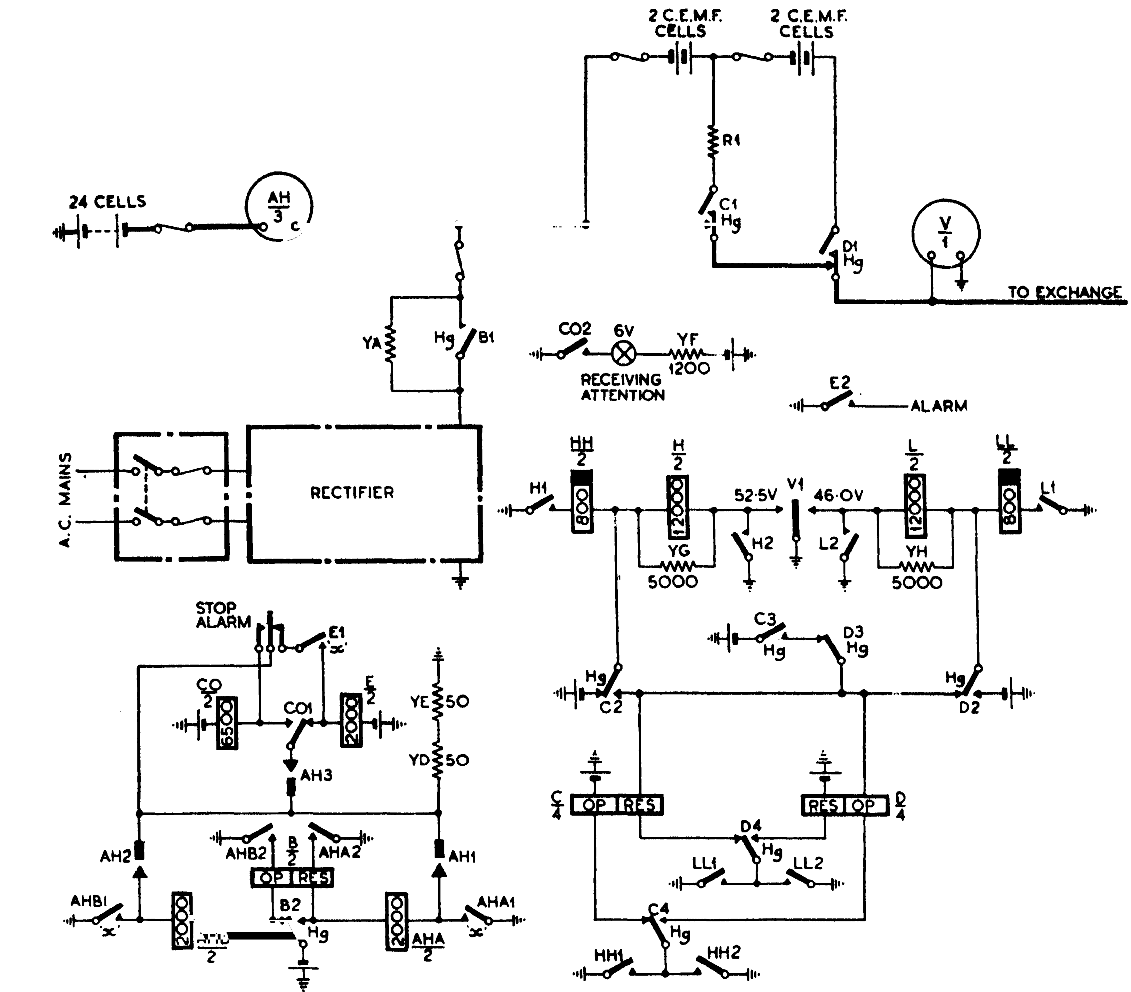


FIG. 798. SINGLE BATTERY AUTOMATIC FLOAT SCHEME

battery float scheme, except for the provision of a single 24-cell battery instead of the two paralleled 25-cell batteries of the larger scheme. A metal rectifier of suitable capacity provides the charging current, and the charge is controlled, as before, by an ampere-hour meter in series with the main battery lead. The terminal p.d. of the battery is not regulated, but the voltage at the exchange busbars is maintained within the permissible limits by the use of two groups each of 2 counter

When the battery is discharged to 4 per cent of its capacity, contact ***AH*2** closes and operates relay *AHB*. ***AHB*2** energizes the operate coil of mercury switch *B*, and ***B*1** in turn connects the charging circuit. ***B*2** disconnects the operating coil of the mercury switch and releases relay *AHB*. Charging now continues until the ampere-hour meter indicates zero, when the closure of contact ***AH*1** operates relay *AHA*. ***AHA*2** now energizes the restoring coil of mercury switch *B*

so that $B1$ disconnects the main charging current.

If the voltage on the exchange busbars reaches the maximum permissible limit, voltmeter contact **$V1$** operates relay H, and **$H1$** in turn operates the relief relay HH. Contacts **$HH1$** and **$HH2$** (provided in duplicate to minimize the risk of failure) energize the operate coil of mercury switch C. C, in operating, switches the first group of counter e.m.f. cells into the discharge lead, and at $C2$ releases H and HH. Contact **$C3$** operates after 5–10 sec to prepare a circuit for a subsequent operation of relay switch D or the restoration of relay switch C.

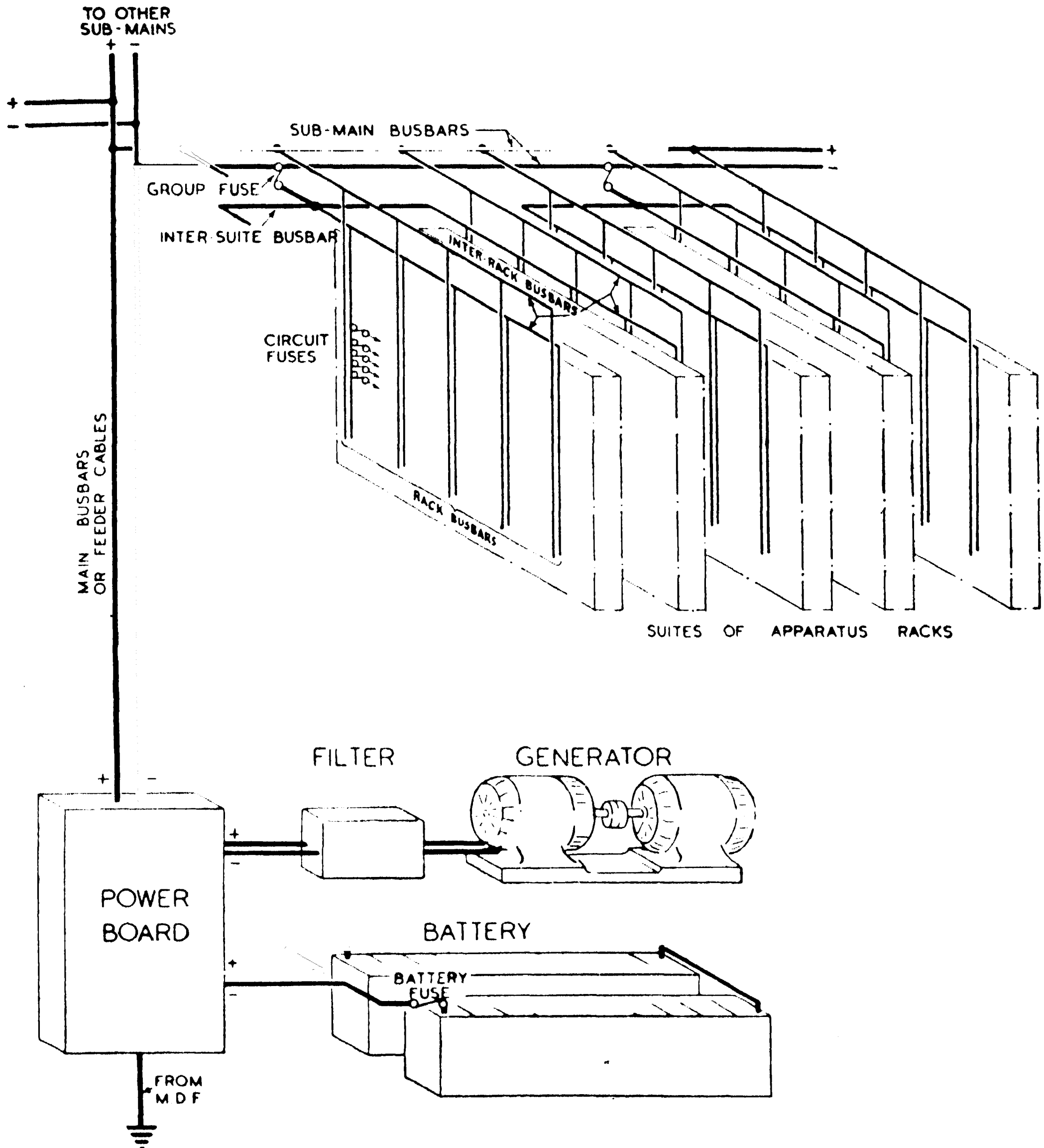


FIG. 799. GENERAL ARRANGEMENTS OF AUTOMATIC EXCHANGE POWER DISTRIBUTION SCHEME (DIAGRAMMATIC)

If there is a further voltage rise such that **$V1$** again makes on its upper contacts, the operate coil of relay D is energized through the circuit previously prepared. The switching of the counter

e.m.f. cells under low-volt conditions is substantially similar, but in this case the operation of contact *V1* on the lower side energizes relays *L* and *LL*.

If the battery discharges to more than 30 per cent, contact ***AH3*** closes to operate relay *E*. Contacts of relay *E* complete the exchange alarm circuit. When the "stop alarm" key is operated, relay *CO* is energized and the holding circuit for relay *E* is broken. Contact ***CO2*** lights the "receiving attention" lamp, whilst the restoration of relay *E* disconnects the earth from the exchange alarm circuit. If the battery now commences to recharge so that contacts *AH*3 break, relay *CO* is released and at *CO*2 dims the "receiving attention" lamp.

Resistors *YD* and *YE* are inserted in the earth connexions to the ampere-hour meter contacts to limit the fault current in the event of a breakdown of the insulation of the ampere-hour meter.

Power Distribution. Fig. 799 shows the general arrangements of the power distribution scheme in an automatic exchange. The generators (or rectifiers) are cabled as loop circuits to the main power board. The batteries are similarly wired as loop circuits, particular care being taken to minimize the impedance of the circuit by running the + and — leads in close proximity. The main earth supply to the exchange is terminated on the M.D.F., and a cable is provided from this point to the power board where the earth connexion to the power system is made.

The automatic exchange equipment may be located on one floor, or may be spread over two or more floors. The power supply to each apparatus room is fed by a system of main feeder cables or busbars. The positioning of these main feeders is of some importance, since a good run may save a considerable expense in the total cost of the power distribution system. In some cases the main feeders are of constant cross-sectional area throughout their length, but more often it is usual to provide only sufficient copper in a particular section of the main feeder system to carry the ultimate current requirements of that section.

The main feeders may be either of busbar construction or may be I.R.V. covered cable. In a large exchange three or more cables may be bunched to provide the requisite cross-sectional area of copper, in which circumstances each cable usually has an effective conductor cross-section of 1 sq in. Where busbars are used, a single bar normally suffices where up to 0·5 sq in. of copper is required, but for larger installations it is preferable to use two, three, or more busbars in parallel. This arrangement enables some degree of standardization in the size of busbars to be achieved, and the laminated construction also increases the surface area of the busbar for cooling purposes. Where bunched cables or laminated busbars are employed, it is usual to bond all the component cables or busbars at each distribution point. Figs. 800 and 801 show typical arrangements of laminated busbars. Simple lap joints are provided between sections of busbar, and good electrical connexion is ensured by the use of substantial

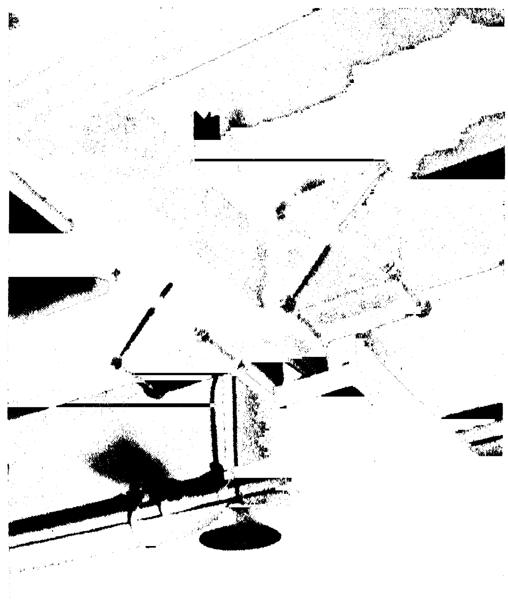


FIG. 800. METHOD OF SUPPORTING AND CLAMPING MAIN FEEDER BUSBARS

clamping plates which are tightened by means of steel bolts.

Each apparatus room is served by a system of "sub-main" busbars which are connected to the main feeders and are run overhead down one of the main gangways of the room. The busbars are supported at intervals by suitably designed mountings which are attached to the end uprights of the apparatus racks. In order to facilitate the supporting arrangements, the sub-main busbars have a standard depth of 2 in., but several thicknesses (i.e. $\frac{1}{4}$ in., $\frac{3}{8}$ in., $\frac{1}{2}$ in.) are available to meet the requirements of exchanges of different size and lay-out. In some cases the sub-main busbars may consist of two 2 in. × $\frac{1}{2}$ in. busbars connected in parallel.

Each individual apparatus rack is provided with vertical busbars located at the front of the rack near the left-hand upright. The busbars of all racks in one suite are connected together by

means of "inter-rack" tie-bars which pass along the suite of racks and are supported from the normal overhead ironwork. Fig. 802 gives details of the clamp joint between the rack and inter-rack busbars. The inter-rack busbars are extended beyond the end of the suite so that connexion can be made to the sub-main busbars. The positive inter-rack busbar is directly connected by means of suitable clamps to the positive sub-main busbar, of a single suite of racks, but in other cases one group fuse can be made to serve two, three, or four suites of racks. In such circumstances inter-suite tie-bars are provided to link the inter-rack busbars of the several suites which are to be supplied from the same group fuse.

The group fuses are omitted in small exchanges where the battery capacity does not exceed 500 Ah. In such cases the inter-rack negative busbar is

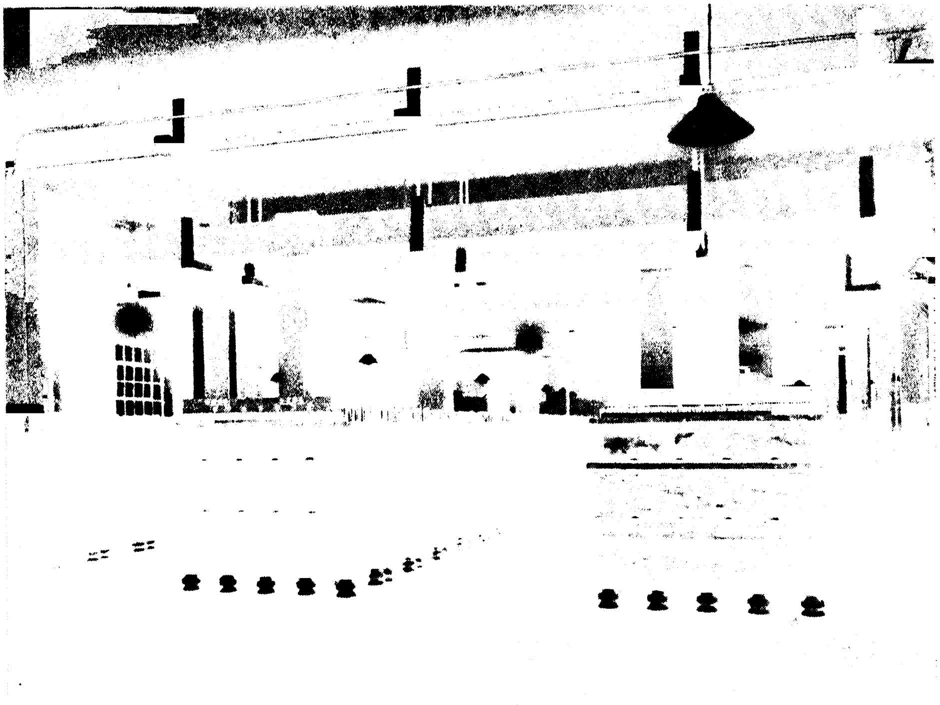


FIG. 801. GENERAL VIEW OF BATTERY ROOM AT LARGE EXCHANGE SHOWING SYSTEM OF BUSBARS

but the negative inter-rack busbar is supplied via a group fuse panel (Fig. 803). This panel is supported from the negative sub-main busbar, and contains two cartridge fuses, alarm fuses, and a fuse alarm lamp. An alarm fuse is connected in parallel with the main cartridge fuse, so that, when the latter operates, the alarm fuse also blows and local contacts set up alarm conditions. The second cartridge fuse is provided to facilitate the restoration of supply in an emergency. It is normally swung out of position, but it can be brought into use quickly with the aid of winged nuts.

The maximum capacity of the "group" fuse is 125 A (rating current). In some cases a fuse of this size is required to supply the current demands terminated directly on the sub-main busbar. Thus, in small exchanges there are no fuses between the circuit fuses on the apparatus rack and the main battery fuses. (Fuses are not provided at the junction of the feeder and the sub-main busbars.)

The rack busbars, the inter-rack busbars, and the inter-suite busbars are of standard dimensions —irrespective of the type of apparatus fitted on the racks. The inter-suite and inter-rack tie-bars are $\frac{3}{4}$ in. × $\frac{1}{2}$ in., whilst the rack busbars are $\frac{1}{2}$ in. × $\frac{1}{4}$ in. The rack busbars are nickel plated, and are drilled with 2 B.A. holes at $\frac{1}{2}$ in. centres throughout their length to receive the distribution fuses. An interesting feature of the power distribution scheme is that the fuses are screwed directly to the rack busbar instead of to some

auxiliary bar in the fuse mounting. The fuse panels are of moulded bakelite, and are screwed to the negative busbar in such a way that the bared face of the bar is exposed for the mounting of fuses. An earth strip is secured to the positive bar at the rear of each fuse mounting, and the return leads of the circuits fed from the panel are connected to this strip. The universal drillings of the busbar enable the fuse mountings to be fixed at any convenient position along the bars. The fuse mounting design is such that all metal parts at negative potential are kept to the front of the panel, whilst those at earth potential are at the rear of the panel. The alarm bar of the mounting is of stainless steel to ensure a good contact surface.

To facilitate identification (and to prevent accidents) all the main, sub-main, and inter-rack

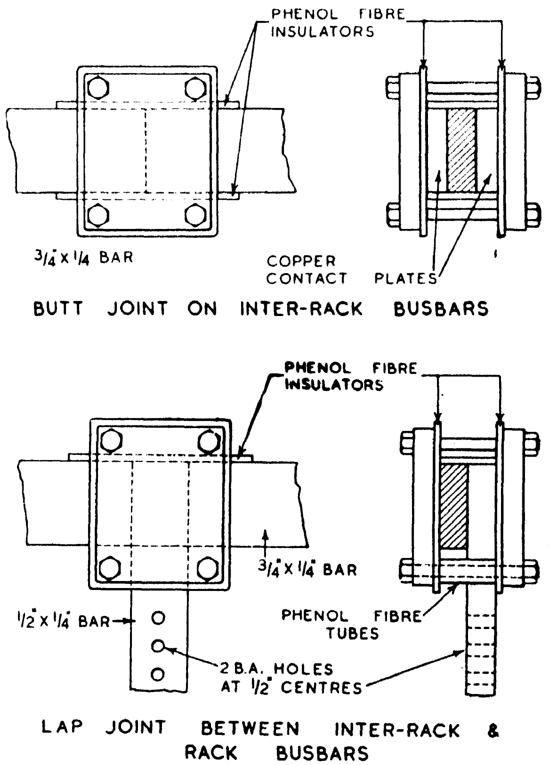


Fig. 802. Arrangement of Joints on Inter-rack and Rack Busbars

earth busbars are painted red. All battery busbars are covered with an insulating paper tube (reinforced with cloth on the more important busbars) and are identified by painting the insulation blue. The positive battery busbars are distinguished by a red line over the blue painted surface.

Size of Conductors. The specifications for the power distribution system of an automatic exchange lay down that there shall be not more than

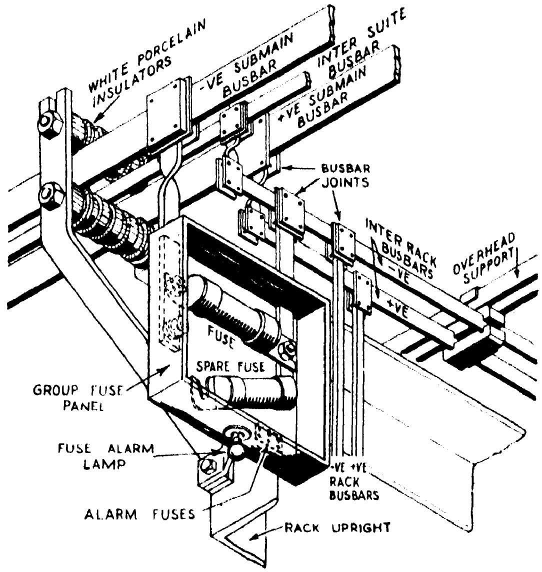


Fig. 803. Construction and Connexions of Group Fuse Panel
(Note inter-suite busbar)

1 V drop in potential between the battery fuses and the most remote rack distribution fuses under maximum load conditions at the ultimate date. The distribution system must also conform to the conductor sizes specified in the I.E.E. Regulations for the Wiring of Buildings. In practice the potential drop requirement is usually the more onerous condition, and the conductors necessary to meet this potential drop condition normally have ample margin against overload.

Figures are available to the design engineer indicating the current requirements of fully-equipped racks of all types. On some racks (e.g. group selector racks) this maximum demand is of the order of 10 A, whilst other racks may require two or three times this current. (A fully-equipped director rack consumes about 25 A under full-load conditions.) From these rack consumption figures it is possible to determine the total current required per suite of racks. This in turn enables the suites to be suitably grouped for service by a group fuse. When the loading and disposition of the group fuses have been settled, it is possible to proceed with the design of the sub-main busbars and the main feeder cables of the exchange. Under normal conditions, there is a potential drop of some 0·25 V between the group fuses and the

rack distribution fuses. This leaves a residue of 0·75 V for the main and sub-main busbars (i.e. from the battery fuses or circuit breakers to the group fuses). An allowance of some 0·1 V must be made for the potential drop in the group fuses.

Calculation of Main and Sub-main Feeder Sizes. The allocation of the potential drop along the main and sub-main feeder system must be considered carefully to obtain the most economical system of distribution. The correct apportionment of the potential drop between the various sections of the feeder system can be determined mathematically for each particular exchange.

For purposes of illustration let it be assumed

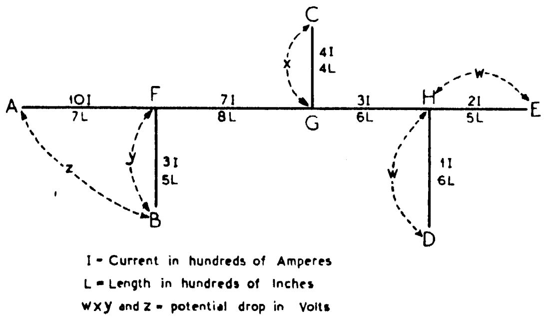


FIG. 804. TYPICAL ARRANGEMENT OF MAIN AND SUB-MAIN FEEDERS

that Fig. 804 shows the main and sub-main feeders of a particular exchange. The main feeder runs from A to H with sub-main busbars connected to distribution points F, G, and H. In order to simplify the calculations, the current in each section of the system has been quoted in hundreds of amperes, and the length of each part of the feeder system is expressed in hundreds of inches. For purposes of examination it is assumed that the potential drops across various parts of the system are as indicated by w, x and y, and that the maximum permissible potential drop to each of the points B, C, D, and E is z.

The cost of a busbar of given material is directly proportional to the length of the busbar and to the cross-sectional area of the bar (i.e. the cost is directly proportional to the volume of copper). The voltage drop in such a section of busbar is directly proportional to the length of the bar and the current through it, and is inversely proportional to the cross-sectional area of the conductor.

Thus, if C = cost,

l = length,

A = cross-sectional area,

I = current,

v = potential drop,

$$C \propto l \times A$$

Also,
$$v \propto \frac{l \times I}{A}$$

or
$$A \propto \frac{l \times I}{v}$$

Substituting for A,

$$C \propto l \times \frac{l \times I}{v} = \frac{l^2 I}{v} \qquad . \qquad . \qquad (1)$$

Applying equation (1) to each section of the distribution scheme illustrated in Fig. 804, the cost can be expressed as follows:

In Section HE, cost $\propto \dfrac{5^2 \times 2}{w} = \dfrac{50}{w}$

In Section HD, cost $\propto \dfrac{6^2 \times 1}{w} = \dfrac{36}{w}$

In Section GH, cost $\propto \dfrac{6^2 \times 3}{x - w} = \dfrac{108}{x - w}$

In Section GC, cost $\propto \dfrac{4^2 \times 4}{x} = \dfrac{64}{x}$

In Section FG, cost $\propto \dfrac{8^2 \times 7}{y - x} = \dfrac{448}{y - x}$

In Section FB, cost $\propto \dfrac{5^2 \times 3}{y} = \dfrac{75}{y}$

In Section AF, cost $\propto \dfrac{7^2 \times 10}{z - y} = \dfrac{490}{z - y}$

The total cost of the feeder system is the summation of the cost of the individual sections, i.e.

Total Cost (C)

$$= \frac{86}{w} + \frac{108}{x - w} + \frac{64}{x} + \frac{448}{y - x} + \frac{75}{y} + \frac{490}{z - y} \qquad (2)$$

If it is assumed for the moment that the potentials x, y, and z are kept constant, it is clear that the potential w can be adjusted to any value between 0 and x by varying the relative cross-sectional areas of sections GH, HE, and HD. The change of cost as w is varied can be found by differentiating as follows:

$$\frac{dC}{dw} \propto -\frac{86}{w^2} + \frac{108}{(x - w)^2}$$

The cost is a minimum when $dC/dw = 0$,

i.e. when
$$\frac{86}{w^2} = \frac{108}{(x - w)^2}$$

or
$$w = 0{\cdot}4715x \qquad . \qquad . \qquad . \qquad (3)$$

This is the most economical relation between w and x—irrespective of the values of w and x—and is quite independent of the other potential

drops in the system. Substituting for w in Equation (2),

$$\text{Total cost } (C) = \frac{451}{x} + \frac{448}{y-x} + \frac{75}{y} + \frac{490}{z-y} \quad (4)$$

If, now, it is assumed that potentials w, y, and z are fixed, and that x is varied between the limits of y and w, the most economical arrangement occurs when $dC/dx = 0$, i.e. when

$$\frac{dC}{dx} \propto -\frac{451}{x^2} + \frac{448}{(y-x)^2} = 0$$

from which $x = 0{\cdot}5007y$. (5)

Substituting for x in Equation (4),

$$\text{Total cost} = \frac{1873}{y} + \frac{490}{z-y} \quad . \quad . \quad (6)$$

If the process is again repeated, but this time assuming that y is variable, the cost is a minimum when $dC/dy = 0$, i.e. when

$$\frac{dC}{dy} \propto -\frac{1873}{y^2} + \frac{490}{(z-y)^2} = 0$$

from which $y = 0{\cdot}6616z$. (7)

We have now the three fundamental relationships:

$$w = 0{\cdot}4715x \text{ (Eq. 3)}$$
$$x = 0{\cdot}5007y \text{ (Eq. 5)}$$
$$y = 0{\cdot}6616z \text{ (Eq. 7)}$$

The total permissible potential drop (z) is specified and hence the potential drop between each junction point can be readily calculated from the above equations. For simplicity, let it

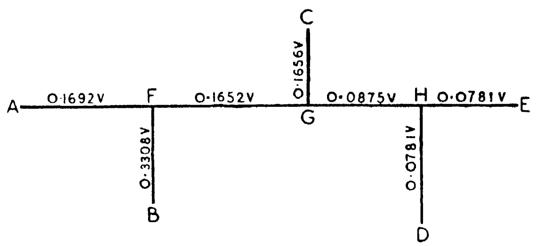


FIG. 805. MOST ECONOMICAL DISTRIBUTION OF POTENTIAL DROP WITH THE FEEDER ARRANGEMENT OF FIG. 804

be assumed that this overall potential drop is 0·5 V under maximum load conditions. The resultant distribution of this potential drop to give the most economical use of copper is as follows:

$$z = 0{\cdot}500 \text{ V}$$
$$y = 0{\cdot}3308 \text{ V}$$
$$x = 0{\cdot}1656 \text{ V}$$
$$w = 0{\cdot}0781 \text{ V}$$

When these figures are applied to the distribution diagram (Fig. 804), the potential drop diagram of Fig. 805 is obtained.

It is now a simple matter to calculate the busbar cross-sections if the specific resistance of the material is known. Assuming that the busbars are of copper with a specific resistance of 0·6622 microhms/in. cube, the following sizes of busbar

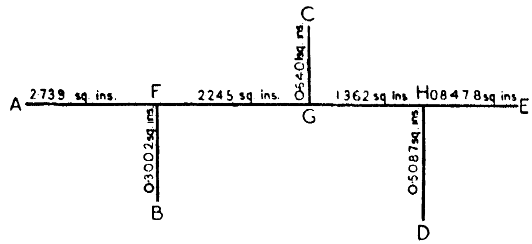


FIG. 806. CALCULATED CONDUCTOR CROSS-SECTIONS TO GIVE THE VOLTAGE DROP DISTRIBUTION OF FIG. 805

are required to provide the calculated voltage drop in each section:

Section AF = 2·739 sq in.
Section FB = 0·3002 sq in.
Section FG = 2·245 sq in.
Section GC = 0·6401 sq in.
Section GH = 1·362 sq in.
Section HD = 0·5087 sq in.
Section HE = 0·8478 sq in.

The combined results are shown in Fig. 806.

Safe Loading of Busbars and Feeder Cables. Although the potential drop requirements usually necessitate the provision of busbar sizes which have an adequate margin of safety, it is important that all conductor cross-sections should be checked to ensure that they will carry the required load without overheating. The heat developed in any conductor is proportional to the square of the current through it, multiplied by the ohmic resistance of the conductor. The heat produced in a unit length of a conductor of circular cross-section is directly proportional to the square of the current and inversely proportional to the square of the radius, i.e.

$$\text{Heat developed} \propto I^2/(\pi r^2)$$

where r is the radius of the conductor.

The heat dissipated under any particular set of conditions is directly proportional to the surface

area of the conductor. For the conductor of circular cross-section:

$$\text{Heat dissipated} \propto 2\pi r \times K$$

where K is a constant which depends largely upon the maximum temperature permissible.

The temperature of the conductor will rise until the rate of dissipation of heat is equal to the rate at which heat is generated by the passage of the current through the conductor.

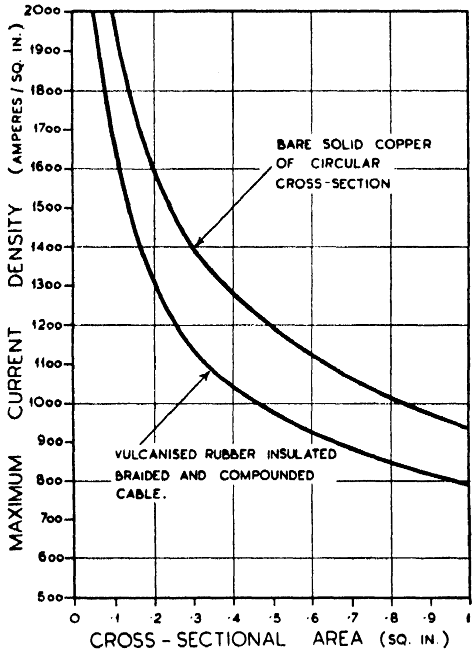


FIG. 807. MAXIMUM PERMISSIBLE CURRENT DENSITY IN CIRCULAR POWER CONDUCTORS

Thus in the balanced state:

$$I^2/(\pi r^2) = 2\pi r \times K$$

from which $$I = \sqrt{2\pi^2 r^3 \times K}$$

The current density in the conductor is obtained by dividing by the cross-sectional area, i.e.

$$\text{Current density} = \frac{I}{\pi r^2} = \frac{\sqrt{2\pi^2 r^3 K}}{\pi r^2} = \sqrt{\frac{K_1}{r}}$$

The maximum permissible current density is therefore a function of the radius of the conductor. As the radius (and hence the cross-sectional area) is made greater, the maximum permissible current density for a given rise of temperature decreases. Conversely, conductors of small gauge will carry a much higher current per square inch of their cross-section than larger feeder cables.

The maximum safe current for any conductor is dependent upon a very wide range of factors (e.g. the proximity of other heat-producing conductors, the shape of the conductor, the covering of the conductor, the surface of the conductor—polished or dull black—and so on). Fig. 807 shows the maximum permissible current density (in amperes per square inch) as specified by the I.E.E. Regulations for the Wiring of Buildings. The higher curve refers to a bare solid copper conductor of circular cross-section, which is run with a spacing of 3 in. from adjacent conductors. The figures are the result of experimental data provided by the British Electrical and Allied Industries Research Association, and are based on a temperature rise of 100° F. The lower curve shows the capacity of vulcanized rubber insulated cables with a permissible temperature rise of 30° F.

The busbars used in automatic telephone exchanges are usually of rectangular section, and their current carrying capacity is somewhat greater than that indicated in Fig. 807. Generally speaking, it is safe to load the busbars of automatic exchanges up to 1000 A/sq in., but this current density can be progressively increased as the cross-sectional area decreases below 1 sq in. A safe figure for large size vulcanized rubber insulated cables is 800 A/sq in. but, here again, the current density can be increased up to 1600 A/sq in. or more for small gauge conductors.

The current densities in the hypothetical distribution system shown in Fig. 804 are as follows:

Section AF . .	365 A/sq in.
Section FB . .	999 A/sq in.
Section FG . .	312 A/sq in.
Section GC . .	625 A/sq in.
Section GH . .	220 A/sq in.
Section HD . .	197 A/sq in.
Section HE . .	236 A/sq in.

All these values are safe if open copper busbars are employed, but section FB is near the borderline if vulcanized rubber feeder cable is used for this spur.

Failure of Battery Supply at Automatic Exchanges. The power distribution arrangements at an automatic exchange are such that the failure of the supply is a comparatively rare occurrence. Generally speaking, the main causes of failure are:

(*a*) The tripping of the battery circuit breaker owing to an excessive load current, or due to an accidental release of the breaker.

(*b*) The blowing of a main fuse resulting from an excessive discharge current produced by faulty circuit conditions.

(c) The changing over from an over-discharged battery to a fully-charged battery, so that the main protective devices operate as a result of the increased current load.

If, for any reason, the battery supply fails, all relays release and complete the circuits for the various driving magnets. The conditions obtaining are such that the instantaneous discharge current immediately after the reconnexion of the supply may be of the order of 4 or 5 times the value of the load before the failure. If the failure occurs when the traffic on the exchange is at a peak, the resultant current when the supply is reconnected may well exceed the fusing current of the main battery fuse or the operating current of the circuit breaker. As a result, it is often found impossible to replace the circuit breakers or fuses, i.e. the breakers or fuses operate immediately they are connected in the discharge lead. In most cases it is necessary to reduce temporarily the exchange load by the withdrawal of a proportion of the group fuses. Generally speaking, the removal of approximately one half of the group fuses should enable the main battery fuse or circuit breaker to hold, even under peak load conditions.

In order to facilitate the rapid removal of the correct group fuses under emergency conditions, it is usual to mark with a vertical white line the mounting boxes of those fuses which must be removed. It is important that a sufficient number of spanners should be provided so that all available staff can assist in the work of restoration. The discharge load at the time of reconnexion can be materially reduced by arranging that those members of the staff, who are not engaged on the removal of feeder fuses, are used to restore the switch mechanisms to their normal position.

Positive Battery Supply. We have seen that a positive battery (i.e. a battery having its negative pole earthed) is often required for metering and for various miscellaneous purposes. In some cases, two secondary cell batteries (each of 25 low-capacity cells) are installed. The idle battery is charged in parallel with the main battery but, since it is of opposite polarity, double-pole switching is used. Fig. 808 shows a typical switching arrangement. All four blades of the four-pole changeover switch are coupled. With float systems, it is usual to install only one positive battery and this is given a continuous trickle charge from a rectifier. This rectifier operates from the public supply mains if these are a.c. and from the a.c. output of the ringing machine if the mains are d.c.

Ringing and Tone Supply. The 16⅔ c/s current required for the ringing of subscribers' bells, and the various tones required by an automatic system, are generated by means of a ringing machine. The construction of these machines and the method of generating the tones have already been described in Volume I. The size of the ringing machine depends primarily upon the volume of traffic on the exchange. For small exchanges with up to 2600 calls in the busy hour, a 15 W

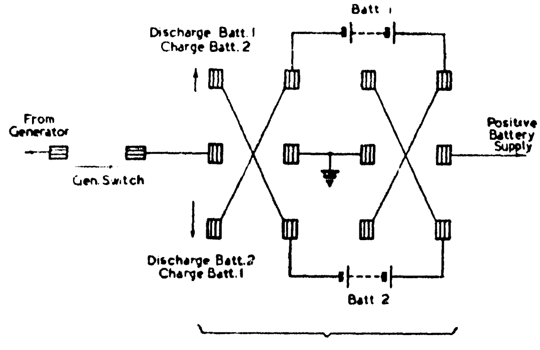


FIG. 808. METHOD OF CHARGING POSITIVE BATTERY IN PARALLEL WITH MAIN BATTERY BY THE USE OF 4-POLE SWITCH

machine (with an output of 0·2 A a.c.) is usually satisfactory. In the very large exchanges a machine of 300 W output may be necessary to meet the demands.

At all except very small exchanges the main ringing machine is driven by a motor from the public mains. In the event of mains failure, a second battery-driven machine is automatically started up, and the various ringing and tone leads are switched to the reserve machine. Typical ringer panels in the power room of an automatic exchange are illustrated in Figs. 794 and 796. The re-setting handle of the automatic changeover switch can be seen in the centre of the left-hand panel in Fig. 796, whilst the tumbler switches towards the upper part of the panel are provided for the testing and isolation of the various ringing phases, etc.

In very small exchanges where it is uneconomical to provide and run a motor-driven ringer, the tones and ringing current are obtained from suitably designed vibrating relays.

EXERCISES XXVII

1. You are informed that the battery at a certain telephone exchange is "floating." Explain precisely what is meant by this. What advantages are gained by floating the battery? (*C. & G. Telephony, Grade II*, 1943.)

2. Explain why different float schemes use a varying number of cells in the main battery. In what circumstances is it advantageous to provide two main batteries?

3. Describe two methods of providing for automatic voltage control of motor-driven d.c. generators. Explain, with suitable sketches, the principle of operation of the voltage regulating devices.

4. Describe briefly the construction and the special maintenance requirements of a counter e.m.f. cell as used in telephone exchange power plant. Explain how counter e.m.f. cells are employed for voltage regulation at an exchange where an automatically controlled power plant is in use. (*C. & G. Telephony, Grade III*, 1944.)

5. Describe, with the aid of a circuit diagram, the main features of an automatically controlled single battery trickle charge power plant for use at a small exchange. (*C. & G. Telephony, Grade III*, 1938.)

6. Draw a schematic diagram of a "floating battery" power plant suitable for supplying an exchange which requires 2500 Ah per day. Describe, concisely, a typical 7-day operation of the plant, including the effective variation in the load during one day.

What procedure should be followed in the event of a temporary breakdown of the public supply mains? (*C. & G. Telephone Exchange Systems II*, 1947.)

7. A 50-volt automatic exchange is to be installed to provide initially for 3000 direct exchange lines (the estimated development at the end of the first 5 years), and it is estimated that development will continue at a uniform rate and will reach a total of 6000 lines at the end of 20 years. Throughout the whole of the 20 years it is assumed that the busy-hour calling rate will be 1·0, and the ratio of the day to busy-hour calling rates will be 7·0. If an average of 0·12 ampere-hour is consumed per call, determine, for a divided battery float system:

(*a*) the ampere-hour capacity of the boxes to be provided for each battery if such capacity is to meet one-half of the 24-hr day load at the end of 20 years,

(*b*) the capacity of the plates to be provided initially in each battery to meet one-half of the 24-hr load at the end of 10 years,

(*c*) the total current output of the charging generators if they are to charge at a rate equal to the 5-year busy-hour discharge current,

(*d*) the cross-section of the battery discharge cables if they are to carry the 20-year load at a current density of 1000 A/sq in.

(*C. & G. Telephone Exchange Systems II*, 1949.)

8. Explain how "noise" can be produced on the speaking circuits of a telephone exchange due to the floating of a d.c. generator. How is such circuit noise measured and how can it be reduced to a tolerable value by means of an electrical filter? What characteristics are required of such a filter and what factors enter into the design of the filter circuit?

9. Describe the method of distributing power to the apparatus in a modern automatic exchange. Show on a diagram the points at which protective fuses or circuit breakers are provided, and explain what factors determine the "rating" of these devices.

10. A direct current supply is fed from a power board at point P to four distribution points, A, B, C, and D, at which 100, 100, 200, and 300 A, respectively, are tapped off. The points are connected by feeder cables as follows: P to A, 5 yd; A to C, 10 yd; and C to D, 25 yd: with a tee from A to B, 15 yd.

Given that 0·5 sq in. cable has a resistance of 0·05 Ω per 1000 yd., determine the most economical cross-sectional area of each cable required to meet the following conditions:

(*a*) the overall voltage drop from the power board to any distribution point A, B, C, or D is not to exceed 1 V;

(*b*) the current density in each cable is to be the same and is not to exceed 1000 A/sq in.;

(*c*) each earth return cable takes the same route and carries the same current as the corresponding battery cable.

(*C. & G. Telephone Exchange Systems II*, 1948.)

APPENDIX I

TRAFFIC CAPACITY TABLES

Contact Number	Traffic Offered to Each Contact when Total Traffic is—									
	1·0	2·0	3·0	4·0	5·0	6·0	7·0	8·0	9·0	10·0
1	1·00000	2·00000	3·00000	4·00000	5·00000	6·00000	7·00000	8·00000	9·00000	10·00000
2	0·50000	1·33333	2·25000	3·20000	4·16667	5·14286	6·12500	7·11111	8·10000	9·09091
3	0·20000	0·80000	1·58824	2·46154	3·37838	4·32000	5·27692	6·24390	7·21782	8·19672
4	0·06250	0·42105	1·03846	1·80281	2·64831	3·54099	4·46283	5·40373	6·35756	7·32054
5	0·01538	0·19048	0·61832	1·24272	1·99172	2·81739	3·69141	4·59705	5·52428	6·46663
6	0·00307	0·07339	0·33016	0·79627	1·42434	2·16240	2·97304	3·83205	4·72417	5·63952
7	0·00051	0·02417	0·15647	0·46865	0·95924	1·58954	2·31931	3·11801	3·96465	4·84515
8	0·00007	0·00688	0·06559	0·25100	0·60259	1·11033	1·74210	2·46532	3·25426	4·09041
9	0·00001	0·00172	0·02440	0·12168	0·35024	0·73126	1·25175	1·88456	2·60242	3·38318
10	—	0·00038	0·00811	0·05336	0·18729	0·45086	0·85471	1·38513	2·01870	2·73208
11	—	0·00008	0·00243	0·02123	0·09192	0·25885	0·55119	0·97329	1·51167	2·14579
12	—	0·00001	0·00066	0·00771	0·04144	0·13795	0·33402	0·65031	1·08739	1·63232
13	—	—	0·00017	0·00257	0·01721	0·06819	0·18957	0·41125	0·74778	1·19739
14	—	—	0·00004	0·00079	0·00661	0·03131	0·10061	0·24532	0·48953	0·84339
15	—	—	0·00001	0·00023	0·00236	0·01342	0·04994	0·13777	0·30407	0·56819
16	—	—	—	0·00006	0·00079	0·00535	0·02323	0·07281	0·17882	0·36497
17	—	—	—	0·00002	0·00025	0·00201	0·01015	0·03624	0·09947	0·22302
18	—	—	—	—	0·00007	0·00071	0·00418	0·01702	0·05236	0·12949
19	—	—	—	—	0·00002	0·00024	0·00162	0·00756	0·02610	0·07142
20	—	—	—	—	0·00001	0·00007	0·00060	0·00318	0·01235	0·03745
21	—	—	—	—	—	0·00002	0·00021	0·00127	0·00555	0·01869
22	—	—	—	—	—	0·00001	0·00007	0·00048	0·00238	0·00889
23	—	—	—	—	—	—	0·00002	0·00018	0·00097	0·00404
24	—	—	—	—	—	—	0·00001	0·00006	0·00038	0·00176
25	—	—	—	—	—	—	—	0·00002	0·00014	0·00073
26	—	—	—	—	—	—	—	0·00001	0·00005	0·00029
27	—	—	—	—	—	—	—	—	0·00002	0·00011
28	—	—	—	—	—	—	—	—	0·00001	0·00004
29	—	—	—	—	—	—	—	—	—	0·00001
30	—	—	—	—	—	—	—	—	—	0·00001

TABLE I. TRAFFIC OFFERED TO EACH CONTACT IN A FULL AVAILABILITY GROUP FOR VARIOUS VALUES OF TOTAL TRAFFIC
(PURE CHANCE TRAFFIC)

Contact Number	Traffic Carried by Each Contact when Total Traffic is—									
	1·0	2·0	3·0	4·0	5·0	6·0	7·0	8·0	9·0	10·0
1	0·50000	0·66667	0·75000	0·80000	0·83333	0·85714	0·87500	0·88889	0·90000	0·90909
2	0·30000	0·53333	0·66176	0·73846	0·78829	0·82286	0·84808	0·86721	0·88218	0·89419
3	0·13750	0·37895	0·54978	0·65873	0·73007	0·77901	0·81409	0·84017	0·86026	0·87618
4	0·04712	0·23057	0·42014	0·56009	0·65659	0·72360	0·77142	0·80668	0·83328	0·85391
5	0·01231	0·11709	0·28816	0·44645	0·56738	0·65499	0·71837	0·76500	0·80011	0·82711
6	0·00256	0·04922	0·17369	0·32762	0·46510	0·57286	0·65373	0·71404	0·75952	0·79437
7	0·00044	0·01729	0·09088	0·21765	0·35665	0·47921	0·57721	0·65269	0·71039	0·75474
8	0·00006	0·00516	0·04119	0·12932	0·25235	0·37907	0·49035	0·58076	0·65184	0·75474
9	—	0·00134	0·01629	0·06832	0·16295	0·28040	0·39704	0·49943	0·58372	0·65110
10	—	0·00030	0·00568	0·03213	0·09537	0·19201	0·30352	0·41184	0·50703	0·58629
11	—	0·00007	0·00177	0·01352	0·05048	0·12090	0·21717	0·32298	0·42428	0·51347
12	—	0·00001	0·00049	0·00514	0·02423	0·06976	0·14445	0·23906	0·33961	0·43493
13	—	—	0·00013	0·00178	0·01060	0·03688	0·08896	0·16593	0·25825	0·35400
14	—	—	0·00003	0·00056	0·00425	0·01789	0·05067	0·10755	0·18546	0·27520
15	—	—	—	0·00016	0·00157	0·00807	0·02671	0·06496	0·12525	0·20322
16	—	—	—	0·00005	0·00054	0·00334	0·01308	0·03659	0·07935	0·14195
17	—	—	—	0·00001	0·00017	0·00130	0·00597	0·01922	0·04711	0·09353
18	—	—	—	—	0·00005	0·00047	0·00256	0·00946	0·02626	0·05807
19	—	—	—	—	0·00002	0·00017	0·00102	0·00438	0·01375	0·03397
20	—	—	—	—	—	0·00005	0·00039	0·00191	0·00680	0·01876
21	—	—	—	—	—	0·00002	0·00014	0·00079	0·00317	0·00980
22	—	—	—	—	—	—	0·00004	0·00030	0·00141	0·00485
23	—	—	—	—	—	—	0·00002	0·00011	0·00059	0·00228
24	—	—	—	—	—	—	—	0·00004	0·00024	0·00103
25	—	—	—	—	—	—	—	0·00002	0·00010	0·00044
26	—	—	—	—	—	—	—	—	0·00004	0·00018
27	—	—	—	—	—	—	—	—	0·00001	0·00007
28	—	—	—	—	—	—	—	—	—	0·00003
29	—	—	—	—	—	—	—	—	—	0·00001
30	—	—	—	—	—	—	—	—	—	—

TABLE II. TRAFFIC CARRIED BY EACH CONTACT IN A FULL AVAILABILITY GROUP FOR VARIOUS VALUES OF TOTAL TRAFFIC
(PURE CHANCE TRAFFIC)

No. of Trunks	Capacity in T.U. for Grade of Service of—			No. of Trunks	Capacity in T.U. for Grade of Service of—		
	0·005	Standard	0·001		0·005	Standard	0·001
1	0·005	0·002	0·001	52	37·6	35·6	34·2
2	0·105	0·065	0·046	54	39·4	37·2	35·8
3	0·35	0·25	0·19	56	41·2	38·9	37·5
4	0·70	0·53	0·43	58	43·0	40·7	39·1
5	1·13	0·90	0·76	60	44·7	42·4	40·8
6	1·62	1·32	1·14	62	46·5	44·1	42·5
7	2·16	1·80	1·58	64	48·3	45·8	44·1
8	2·73	2·31	2·05	66	50·1	47·6	45·8
9	3·33	2·85	2·56	68	51·9	49·3	47·5
10	3·96	3·43	3·09	70	53·7	51·0	49·2
11	4·61	4·02	3·65	72	55·5	52·7	50·9
12	5·28	4·63	4·23	74	57·3	54·4	52·6
13	5·97	5·27	4·83	76	59·1	56·1	54·3
14	6·63	5·92	5·44	78	60·9	57·8	56·1
15	7·38	6·58	6·08	80	62·7	59·4	57·8
16	8·10	7·26	6·72	82	64·5	61·1	59·5
17	8·84	7·95	7·38	84	66·3	62·8	61·3
18	9·58	8·64	8·04	86	68·1	64·5	63·0
19	10·34	9·35	8·72	88	69·9	66·2	64·8
20	11·10	10·07	9·41	90	71·8	67·9	66·5
21	11·87	10·80	10·11	92	73·6	69·6	68·3
22	12·64	11·53	10·81	94	75·4	71·3	70·0
23	13·42	12·27	11·52	96	77·2	73·0	71·8
24	14·21	13·01	12·24	98	79·1	74·7	73·5
25	15·0	13·76	13·0	100	80·9	76·4	75·3
26	15·8	14·5	13·7	104	84·6	79·9	78·8
27	16·6	15·3	14·4	108	88·3	83·3	82·3
28	17·4	16·1	15·2	112	92·0	86·7	85·9
29	18·2	16·9	15·9	116	95·7	90·2	89·4
30	19·0	17·7	16·7	120	99·4	93·6	93·0
31	19·8	18·4	17·4	124	103·1	97·0	96·5
32	20·6	19·2	18·2	128	106·8	100·5	100·1
33	21·4	20·0	18·9	132	110·6	104·0	103·7
34	22·3	20·8	19·7	136	114·3	107·5	107·3
35	23·1	21·6	20·5	140	118·0	111·0	110·9
36	23·9	22·4	21·3	144	121·8	114·5	114·5
37	24·8	23·2	22·1	148	125·5	117·9	118·1
38	25·6	24·0	22·9	152	129·3	121·4	121·8
39	26·5	24·9	23·7	156	133·0	124·8	125·4
40	27·3	25·7	24·5	160	136·8	128·2	129·0
41	28·2	26·5	25·3	164	140·6	131·7	132·7
42	29·0	27·3	26·1	168	144·3	135·1	136·3
43	29·9	28·1	26·9	172	148·1	138·6	139·9
44	30·8	28·9	27·7	176	151·9	142·2	143·6
45	31·6	29·7	28·5	180	155·7	145·8	147·2
46	32·5	30·5	29·3	184	159·5	149·3	150·9
47	33·3	31·4	30·1	188	163·3	152·9	154·6
48	34·2	32·2	30·9	192	167·0	156·4	158·3
49	35·1	33·0	31·7	196	170·8	159·9	162·0
50	35·9	33·9	32·5	200	174·6	163·4	165·6

Note 1. The standard grade of service is such that, on an average, there is one lost call in 500 subject to the proviso that the grade of service does not fall below one lost call in 100 if the traffic increases by 10 per cent.

Note 2. The number of trunks required for intermediate values of traffic can be obtained, with sufficient accuracy for most practical purposes, by interpolation of the above figures.

TABLE III. TRAFFIC CAPACITY OF FULL AVAILABILITY GROUPS (PURE CHANCE TRAFFIC)

No. of Trunks	Capacity in T.U. for Grade of Service of—			No. of Trunks	Capacity in T.U. for Grade of Service of—		
	0·005	Standard	0·001		0·005	Standard	0·001
1	0·005	0·002	0·001	52	24·88	22·16	20·35
2	0·105	0·065	0·046	54	25·87	23·05	21·17
3	0·35	0·25	0·19	56	26·87	23·95	22·00
4	0·70	0·53	0·43	58	27·86	24·84	22·82
5	1·13	0·90	0·76	60	28·86	25·73	23·64
6	1·62	1·32	1·14	62	29·86	26·62	24·46
7	2·16	1·80	1·58	64	30·85	27·51	25·28
8	2·73	2·31	2·05	66	31·85	28·41	26·11
9	3·33	2·85	2·56	68	32·84	29·30	26·93
10	3·96	3·43	3·09	70	33·84	30·19	27·75
11	4·46	3·88	3·50	72	34·84	31·08	28·57
12	4·96	4·32	3·91	74	35·83	31·97	29·39
13	5·45	4·77	4·32	76	36·83	32·87	30·22
14	5·95	5·21	4·73	78	37·82	33·76	31·04
15	6·45	5·66	5·15	80	38·82	34·65	31·86
16	6·95	6·11	5·56	82	39·82	35·54	32·68
17	7·45	6·55	5·97	84	40·81	36·43	33·50
18	7·94	7·00	6·38	86	41·81	37·33	34·33
19	8·44	7·44	6·79	88	42·80	38·22	35·15
20	8·94	7·89	7·20	90	43·80	39·11	35·97
21	9·44	8·34	7·61	92	44·80	40·00	36·79
22	9·94	8·78	8·02	94	45·79	40·89	37·61
23	10·43	9·23	8·43	96	46·79	41·79	38·44
24	10·93	9·67	8·84	98	47·78	42·68	39·26
25	11·43	10·12	9·26	100	48·78	43·57	40·08
26	11·93	10·57	9·67	104	50·8	45·4	41·7
27	12·43	11·01	10·08	108	52·8	47·1	43·4
28	12·92	11·46	10·49	112	54·8	48·9	45·0
29	13·42	11·90	10·90	116	56·7	50·7	46·7
30	13·92	12·35	11·31	120	58·7	52·5	48·3
31	14·42	12·80	11·72	124	60·7	54·3	49·9
32	14·92	13·24	12·13	128	62·7	56·1	51·6
33	15·41	13·69	12·54	132	64·7	57·8	53·2
34	15·91	14·13	12·95	136	66·7	59·6	54·9
35	16·41	14·58	13·37	140	68·7	61·4	56·5
36	16·91	15·03	13·78	144	70·7	63·2	58·2
37	17·41	15·47	14·19	148	72·7	65·0	59·8
38	17·90	15·92	14·60	152	74·7	66·8	61·5
39	18·40	16·36	15·01	156	76·7	68·6	63·1
40	18·90	16·81	15·42	160	78·7	70·3	64·7
41	19·40	17·26	15·83	164	80·7	72·1	66·4
42	19·90	17·70	16·24	168	82·6	73·9	68·0
43	20·39	18·15	16·65	172	84·6	75·7	69·7
44	20·89	18·59	17·06	176	86·6	77·5	71·3
45	21·39	19·04	17·48	180	88·6	79·3	73·0
46	21·89	19·49	17·89	184	90·6	81·0	74·6
47	22·39	19·93	18·30	188	92·6	82·8	76·2
48	22·88	20·38	18·71	192	94·6	84·6	77·9
49	23·38	20·82	19·12	196	96·6	86·4	79·5
50	23·88	21·27	19·53	200	98·6	88·2	81·2

Note 1. The standard grade of service is such that, on an average, there is one lost call in 500 subject to the proviso that the grade of service does not fall below one lost call in 100 if the traffic increases by 10 per cent.

Note 2. The number of trunks required for intermediate values of traffic can be obtained, with sufficient accuracy for most practical purposes, by interpolation of the above figures.

Note 3. The traffic capacities of groups up to 10 trunks are the full availability figures.

TABLE IV. TRAFFIC CAPACITY OF GRADED GROUPS WITH AN AVAILABILITY OF 10
(PURE CHANCE TRAFFIC)

No. of Trunks	Capacity in T.U. for Grade of Service of—			No. of Trunks	Capacity in T.U. for Grade of Service of—		
	0·005	Standard	0·001		0·005	Standard	0·001
1	0·005	0·002	0·001	52	32·49	30·07	28·47
2	0·105	0·065	0·046	54	33·82	31·32	29·66
3	0·35	0·25	0·19	56	35·16	32·57	30·86
4	0·70	0·53	0·43	58	36·50	33·82	32·05
5	1·13	0·90	0·76	60	37·83	35·07	33·24
6	1·62	1·32	1·14	62	39·17	36·32	34·43
7	2·16	1·80	1·58	64	40·50	37·57	35·62
8	2·73	2·31	2·05	66	41·84	38·82	36·82
9	3·33	2·85	2·56	68	43·18	40·07	38·01
10	3·96	3·43	3·09	70	44·51	41·32	39·20
11	4·61	4·02	3·65	72	45·85	42·57	40·39
12	5·28	4·63	4·23	74	47·18	43·82	41·58
13	5·97	5·27	4·83	76	48·52	45·07	42·78
14	6·63	5·92	5·44	78	49·85	46·32	43·97
15	7·38	6·58	6·08	80	51·19	47·57	45·16
16	8·10	7·26	6·72	82	52·52	48·82	46·35
17	8·84	7·95	7·38	84	53·86	50·07	47·54
18	9·58	8·64	8·04	86	55·19	51·32	48·74
19	10·34	9·35	8·72	88	56·53	52·57	49·93
20	11·10	10·07	9·41	90	57·87	53·82	51·12
21	11·78	10·70	10·00	92	59·20	55·07	52·31
22	12·45	11·32	10·59	94	60·54	56·32	53·50
23	13·11	11·95	11·19	96	61·87	57·57	54·70
24	13·78	12·57	11·78	98	63·21	58·82	55·89
25	14·45	13·20	12·38	100	64·55	60·07	57·08
26	15·12	13·82	12·98	104	67·2	62·6	59·5
27	15·79	14·45	13·57	108	69·9	65·1	61·8
28	16·45	15·07	14·17	112	72·6	67·6	64·2
29	17·12	15·70	14·76	116	75·2	70·1	66·6
30	17·79	16·32	15·36	120	77·9	72·6	69·0
31	18·46	16·95	15·96	124	80·6	75·1	71·4
32	19·13	17·57	16·55	128	83·3	77·6	73·8
33	19·79	18·20	17·15	132	85·9	80·1	76·2
34	20·46	18·82	17·74	136	88·6	82·6	78·5
35	21·13	19·45	18·34	140	91·3	85·1	80·9
36	21·80	20·07	18·94	144	93·9	87·6	83·3
37	22·47	20·70	19·53	148	96·6	90·1	85·7
38	23·13	21·32	20·13	152	99·3	92·6	88·1
39	23·80	21·95	20·72	156	102·0	95·1	90·5
40	24·47	22·57	21·32	160	104·6	97·6	92·8
41	25·14	23·20	21·92	164	107·3	100·1	95·2
42	25·81	23·82	22·51	168	110·0	102·6	97·6
43	26·47	24·45	23·11	172	112·6	105·1	100·0
44	27·14	25·07	23·70	176	115·3	107·6	102·4
45	27·81	25·70	24·30	180	118·0	110·1	104·8
46	28·48	26·32	24·90	184	120·7	112·6	107·1
47	29·15	26·95	25·49	188	123·3	115·1	109·5
48	29·81	27·57	26·09	192	126·0	117·6	111·9
49	30·48	28·20	26·68	196	128·7	120·1	114·3
50	31·15	28·82	27·28	200	131·4	122·6	116·7

Note 1. The standard grade of service is such that, on an average, there is one lost call in 500 subject to the proviso that the grade of service does not fall below one lost call in 100 if the traffic increases by 10 per cent.

Note 2. The number of trunks required for intermediate values of traffic can be obtained, with sufficient accuracy for most practical purposes, by interpolation of the above figures.

Note 3. The traffic capacities of groups up to 20 trunks are the full availability figures.

TABLE V. TRAFFIC CAPACITY OF GRADED GROUPS WITH AN AVAILABILITY OF 20 (PURE CHANCE TRAFFIC)

No. of Trunks	Capacity in T.U. for Grade of Service of—			No. of Trunks	Capacity in T.U for Grade of Service of—		
	0·005	Standard	0·001		0·005	Standard	0·001
1	0·005	0·002	0·001	52	35·63	33·53	32·07
2	0·105	0·065	0·046	54	37·17	34·99	33·48
3	0·35	0·25	0·19	56	38·70	36·46	34·90
4	0·70	0·53	0·43	58	40·24	37·92	36·31
5	1·13	0·90	0·76	60	41·77	39·39	37·73
6	1·62	1·32	1·14	62	43·30	40·86	39·15
7	2·16	1·80	1·58	64	44·84	42·32	40·56
8	2·73	2·31	2·05	66	46·37	43·79	41·98
9	3·33	2·85	2·56	68	47·91	45·25	43·39
10	3·96	3·43	3·09	70	49·44	46·72	44·81
11	4·61	4·02	3·65	72	50·97	48·19	46·23
12	5·28	4·63	4·23	74	52·51	49·65	47·64
13	5·97	5·27	4·83	76	54·04	51·12	49·06
14	6·63	5·92	5·44	78	55·58	52·58	50·47
15	7·38	6·58	6·08	80	57·11	54·05	51·89
16	8·10	7·26	6·72	82	58·64	55·52	53·31
17	8·84	7·95	7·38	84	60·18	56·98	54·72
18	9·58	8·64	8·04	86	61·71	58·45	56·14
19	10·34	9·35	8·72	88	63·25	59·91	57·55
20	11·10	10·07	9·41	90	64·78	61·38	58·97
21	11·86	10·80	10·12	92	66·31	62·85	60·39
22	12·62	11·54	10·83	94	67·85	64·31	61·80
23	13·39	12·27	11·53	96	69·38	65·78	63·22
24	14·16	13·00	12·24	98	70·92	67·24	64·63
25	14·93	13·74	12·95	100	72·45	68·69	66·05
26	15·69	14·47	13·66	104	75·5	71·6	68·9
27	16·46	15·20	14·37	108	78·6	74·5	71·7
28	17·23	15·93	15·07	112	81·7	77·4	74·5
29	17·99	16·67	15·78	116	84·7	80·2	77·4
30	18·76	17·40	16·49	120	87·8	83·1	80·2
31	19·53	18·13	17·20	124	90·9	86·0	83·0
32	20·29	18·87	17·91	128	93·9	88·9	85·9
33	21·06	19·60	18·61	132	97·0	91·8	88·7
34	21·83	20·33	19·32	136	100·1	94·7	91·5
35	22·60	21·07	20·03	140	103·1	97·6	94·4
36	23·36	21·80	20·74	144	106·2	100·5	97·2
37	24·13	22·53	21·45	148	109·3	103·3	100·0
38	24·90	23·26	22·15	152	112·3	106·2	102·9
39	25·66	24·00	22·86	156	115·4	109·1	105·7
40	26·43	24·73	23·57	160	118·5	112·0	108·5
41	27·20	25·46	24·28	164	121·5	114·9	111·4
42	27·96	26·20	24·99	168	124·6	117·8	114·2
43	28·73	26·93	25·69	172	127·7	120·7	117·0
44	29·50	27·66	26·40	176	130·7	123·6	119·9
45	30·27	28·40	27·11	180	133·8	126·5	122·7
46	31·03	29·13	27·82	184	136·9	129·3	125·5
47	31·80	29·86	28·53	188	139·9	132·2	128·4
48	32·57	30·59	29·23	192	143·0	135·1	131·2
49	33·33	31·33	29·94	196	146·1	138·0	134·0
50	34·10	32·06	30·65	200	149·2	140·9	136·9

Note 1. The standard grade of service is such that, on an average, there is one lost call in 500 subject to the proviso that the grade of service does not fall below one lost call in 100 if the traffic increases by 10 per cent.

Note 2. The number of trunks required for intermediate values of traffic can be obtained, with sufficient accuracy for most practical purposes, by interpolation of the above figures.

Note 3. The traffic capacities of groups up to 20 trunks are the full availability figures.

TABLE VI. TRAFFIC CAPACITY OF GRADED GROUPS WITH AN AVAILABILITY OF 20 (TRAFFIC SMOOTHED BY GRADING ARRANGEMENTS)

No. of Trunks	Capacity in T.U. for Grade of Service of—			No. of Trunks	Capacity in T.U. for Grade of Service of—		
	0·005	Standard	0·001		0·005	Standard	0·001
1	0·005	0·002	0·001	52	33·89	31·61	30·07
2	0·105	0·065	0·046	54	35·29	32·94	31·35
3	0·35	0·25	0·19	56	36·70	34·26	32·62
4	0·70	0·53	0·43	58	38·11	35·59	33·90
5	1·13	0·90	0·76	60	39·51	36·92	35·17
6	1·62	1·32	1·14	62	40·92	38·25	36·44
7	2·16	1·80	1·58	64	42·32	39·58	37·72
8	2·73	2·31	2·05	66	43·73	40·90	38·89
9	3·33	2·85	2·56	68	45·13	42·23	40·27
10	3·96	3·43	3·09	70	46·54	43·56	41·54
11	4·61	4·02	3·65	72	47·95	44·89	42·81
12	5·28	4·63	4·23	74	49·35	46·22	44·09
13	5·97	5·27	4·83	76	50·76	47·54	45·36
14	6·63	5·92	5·44	78	52·16	48·87	46·64
15	7·38	6·58	6·08	80	53·57	50·20	47·91
16	8·10	7·26	6·72	82	54·98	51·53	49·18
17	8·84	7·95	7·38	84	56·38	52·86	50·46
18	9·58	8·64	8·04	86	57·79	54·18	51·73
19	10·34	9·35	8·72	88	59·19	55·51	53·01
20	11·10	10·07	9·41	90	60·60	56·84	54·28
21	11·87	10·80	10·11	92	62·01	58·17	55·55
22	12·64	11·53	11·81	94	63·41	59·50	56·83
23	13·42	12·27	11·52	96	64·82	60·82	58·10
24	14·21	13·01	12·24	98	66·23	62·15	59·38
25	14·91	13·68	12·88	100	67·63	63·48	60·65
26	15·61	14·34	13·51	104	70·4	66·1	63·2
27	16·31	15·01	14·15	108	73·3	68·8	65·8
28	17·02	15·67	14·79	112	76·1	71·5	68·3
29	17·72	16·34	15·42	116	78·9	74·1	70·8
30	18·42	17·00	16·06	120	81·7	76·8	73·4
31	19·12	17·66	16·70	124	84·5	79·4	75·9
32	19·83	18·33	17·33	128	87·3	82·1	78·5
33	20·53	18·99	17·97	132	90·1	84·7	81·0
34	21·23	19·66	18·61	136	92·9	87·4	83·6
35	21·93	20·32	19·25	140	95·8	90·0	86·1
36	22·64	20·98	19·88	144	98·6	92·7	88·7
37	23·34	21·65	20·52	148	101·4	95·4	91·2
38	24·04	22·31	21·16	152	104·2	98·0	93·8
39	24·75	22·98	21·79	156	107·0	100·7	96·3
40	25·45	23·64	22·43	160	109·8	103·3	98·9
41	26·15	24·30	23·07	164	112·6	106·0	101·4
42	26·86	24·97	23·70	168	115·4	108·6	104·0
43	27·56	25·63	24·34	172	118·2	111·3	106·5
44	28·26	26·30	24·98	176	121·1	113·9	109·1
45	28·97	26·96	25·62	180	123·9	116·6	111·6
46	29·67	27·62	26·25	184	126·7	119·3	114·2
47	30·37	28·29	26·89	188	129·5	121·9	116·7
48	31·07	28·95	27·53	192	132·3	124·6	119·3
49	31·78	29·62	28·16	196	135·1	127·2	121·8
50	32·48	30·28	28·80	200	137·9	129·9	124·4

Note 1. The standard grade of service is such that, on an average, there is one lost call in 500 subject to the proviso that the grade of service does not fall below one lost call in 100 if the traffic increases by 10 per cent.

Note 2. The number of trunks required for intermediate values of traffic can be obtained, with sufficient accuracy for most practical purposes, by interpolation of the above figures.

Note 3. The traffic capacities of groups up to 24 trunks are the full availability figures.

TABLE VII. TRAFFIC CAPACITY OF GRADED GROUPS WITH AN AVAILABILITY OF 24 (PURE CHANCE TRAFFIC)

No. of Trunks	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Individuals	0	0	1	1	1	1	1	1	1	2	2	2	2	3	3	3	4	4	4	4
Pairs	1	2	0	1	2	3	4	5	6	4	5	6	7	5	6	7	5	6	7	8
Commons	19	18	19	18	17	16	15	14	13	14	13	12	11	12	11	10	11	10	9	8

4-group Gradings

No. of Trunks	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Individuals	0	0	0	0	0	0	1	1	1	1	2	2	2	2	2	3	3	3	3	3
Pairs	3	3	3	4	4	5	3	3	4	5	3	3	4	4	4	3	3	4	4	5
Threes	5	6	7	6	7	6	6	7	6	5	5	6	5	6	7	5	6	5	6	5
Commons	12	11	10	10	9	9	10	9	9	9	10	9	9	8	7	9	8	8	7	7

6-group Gradings

No. of Trunks	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Individuals	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3
Pairs	2	3	3	4	4	4	5	3	3	3	4	4	4	5	5	5	6	6	4	4
Fours	8	6	7	5	6	7	5	5	6	7	5	6	7	5	6	7	5	6	6	7
Commons	9	10	9	10	9	8	9	10	9	8	9	8	7	8	7	6	7	6	7	6

8-group Gradings

No. of Trunks	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Individuals	2	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4
Pairs	4	2	2	3	3	3	3	4	4	4	5	5	5	3	3	4	4	4	5	5
Fives	7	7	8	5	6	7	8	5	6	7	4	5	6	6	7	4	5	6	3	4
Commons	7	8	7	9	8	7	6	8	7	6	8	7	6	7	6	8	7	6	8	7

10-group Gradings

No. of Trunks	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Individuals	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4
Pairs	3	4	4	2	2	2	3	3	3	3	4	4	4	4	5	5	3	3	3	3
Threes	4	3	3	3	4	4	3	3	4	4	3	3	3	4	3	3	3	3	3	4
Fours	4	4	4	4	3	4	3	4	3	3	3	3	4	3	3	3	3	3	4	3
Sixes	4	3	4	4	4	3	4	3	3	4	3	4	3	3	2	3	3	4	3	3
Commons	3	4	3	4	4	4	4	4	4	3	4	3	3	3	4	3	4	3	3	3

12-group Gradings

TABLE VIII. TYPICAL GRADING FORMATIONS FOR AN AVAILABILITY OF 20

APPENDIX II

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APPENDIX III

ANSWERS TO NUMERICAL EXERCISES

Exercises II

2. Traffic offered to group = 10·02 T.U.

3. (*a*) Grade of service = 0·21.
(*b*) Traffic carried by first choice trunk = 0·66 T.U.

7. Smoothest grading is 3, 2, 2, 3.

8. Meter reading = 3 calls.

9. Traffic carried by each first choice trunk = 0·333 T.U.
Traffic carried by second choice trunk = 0·363 T.U.
Traffic carried by third choice trunk = 0·192 T.U.
Traffic carried by fourth choice trunk = 0·079 T.U.

10. (*a*) Proportional increase is 0·287.
(*b*) ,, ,, 0·582.

Exercises III

10. (*a*) 6·014 lb.
(*b*) 1·002 lb.
(*c*) 5·55 lb and 0·925 lb.

Exercises VII

10. (*a*) Relay (i) is quicker.
(*b*) (i) 2·4 msec, (ii) 3·0 msec.

Exercises IX

6. 14·6 ohms.

Exercises XII

2. Grade of service deteriorates to 0·4. By commoning the groups of the grading to give full availability, the grade of service can be increased to 0·2356.

10. (*a*) 20 miles.
(*b*) 19·63 miles.
(*c*) 19 miles.

Exercises XIV

3. Grade of service = 0·00625 with 4 links.
,, ,, = 0·0335 ,, 3 ,,

Exercises XV

3. 3 A-units each with 7 group selectors and 5 final selectors.

Exercises XVI

5. 36 final selectors are required under the new conditions. Since there is a capacity for 19 + 1 T.O. selectors on the standard A-unit, the proposed addition cannot be made without adversely affecting the service of the group.

Exercises XIX

2. (*a*) With a 2-motion selector 6, 75, 61, 48, and 10 trunks are required for levels 1, 2, 3, 4, and 0 respectively. Levels 2, 3, and 4 require gradings.
(*b*) With a uniselector type mechanism it is possible to provide full availability conditions throughout and 6, 69, 58, 46, and 10 trunks are required for levels 1, 2, 3, 4, and 0 respectively.

Exercises XX

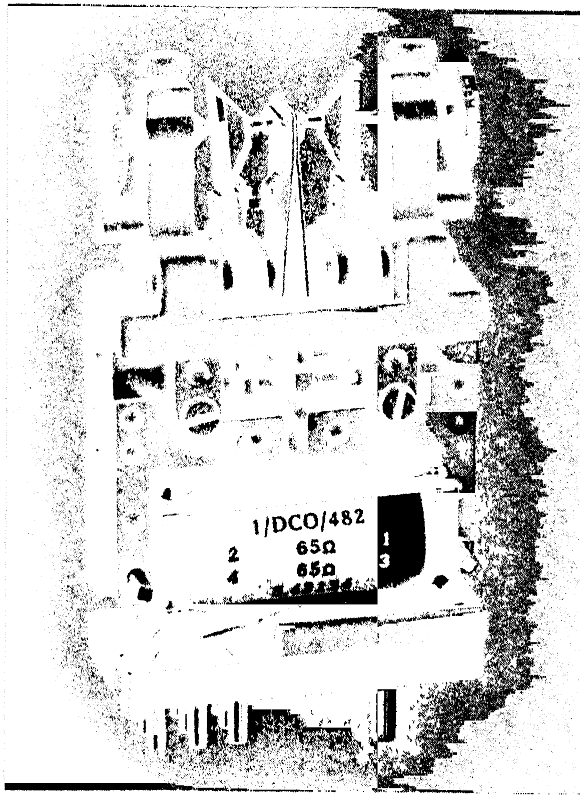
10. 196 office selectors on 4 frames.

Exercises XXVII

7. (*a*) 2520 Ah.
(*b*) 1680 Ah.
(*c*) 360 A.
(*d*) 0·72 sq in.

10. P to A = 1·4 sq. in.
A to C = 1·0 sq. in.
C to D = 0·6 sq. in.
A to B = 0·2 sq. in.

INDEX


1/DCO/482
2 65Ω
4 65Ω
1
3